COMBUSTION

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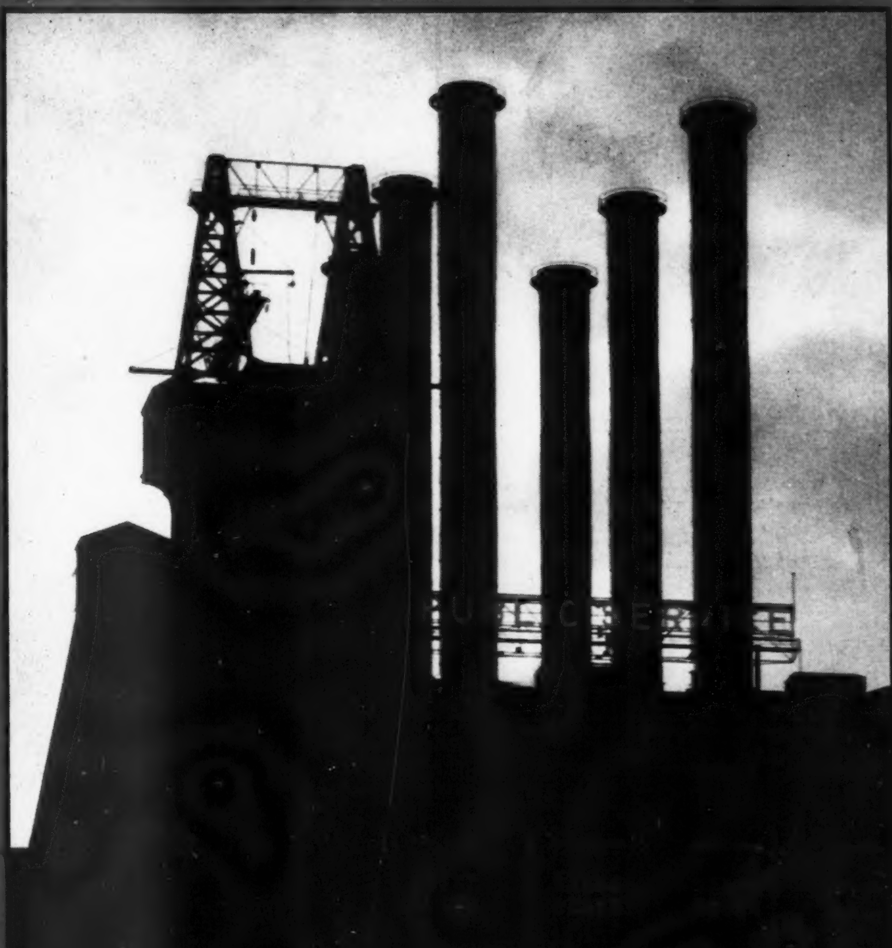

Trends in the Design of Coal Handling Systems
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COMBUSTION

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COMBUSTION

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What Do I Wish? What Can I Do?

B. H. WITHERSPOON

TWO hundred young Americans—embryo artillery officers — stood at rigid attention awaiting in the graying dawn the customary procedure of the formation. Across the cobblestones of the old drill yard of this famous French Military School briskly strode "Mon-Capitaine"—senior instructor. Halting with a snap and alertness peculiar to his race and training, a happy smile mellowing the stamp of military discipline upon his face he said, "Good morning, gentlemen. Remember today, as always, ask yourself first—'What do I wish', and second, 'What can I do'."

Through the intervening years this very effective wartime formula has proven, and will always prove, a most effective peacetime formula.

Nothing new about the idea. It is as old as history. Everyone has used it or uses it—more or less. That is the trouble—that the "less" should be there at at all. Happily the "less" is becoming "less" as the new era of "thirst for knowledge" gets under way in American business. This era which, broadly speaking and referring particularly to industry, may be dated from the present century—has seen the quest for facts broaden from the few to the many—from the mighty corporation to all phases and sizes of industry.

"I don't know where I am going but I am on my way," may have appealed to the adventurous spirit of yesterday but it is manifestly out of step with the industrial spirit of today. "What Can I Do" is the motive power behind modern research—the craving for facts—the seeking of the unknown—the finding of the answer to known and hidden problems.

The growth of research is astounding but all that has been done in this connection is as nothing compared with the use industry will make in the future of facilities for obtaining facts and, having obtained them, for using them as the direct assets of management.

No field has seen greater strides in research than the Power and Combustion field. Innumerable problems have been solved—yet vastly more remain unsolved.

Complete laboratory facilities, equipment and personnel are expensive to install, organize and maintain. Companies which cannot justify this expense are finding that their research problems can be economically handled by the independent laboratory of which there are a number today offering every facility of equipment and personnel.

Some companies turn their problems over bodily—others wish to place their own research man at the independent laboratory, to work out their particular problems in collaboration with the laboratory's staff.

C. F. Kettering, Director of Research, General Motors Corporation, refers to Research as a "Department of Change-making" and states "Your business will change whether you want it to or whether you do not and you had better study how changes come into business . . . If you are willing to sit down and admit that there are some things wrong with your business and wrong with your product and write them down on the wall and then start out and systematically fix those things, that is another way to get into research business."

Certainly an effective way of stating in different words the thoughts of "Mon-Capitaine"—"What Do I Wish"—"What Can I Do?"

B H Witherspoon

President
PITTSBURGH TESTING LABORATORY

E D I T O R I A L

Science Opens the Door

IN his brilliant book, "The Universe Around Us," Sir James Jeans marks an evening in 1610 as the dividing line between star gazing and scientific astronomy. It was then that Galileo, Professor of Mathematics in the University of Padua, first turned his telescope on Jupiter and saw in the four satellites circling that great planet a replica of the solar system.

That telescope laid bare the secrets of the sky, which for countless centuries had hid just beyond the ken of human understanding. Thus, age old fallacies and superstitions were exposed and dismissed as knowledge supplanted myth and legend.

Like astronomy, other phases of human endeavor eventually reach a stage of development where further progress can come only through the aid of science in pointing out new paths of advancement.

As an example, the standards of combustion and steam engineering have long since advanced beyond the point where the practical engineer of the old school can contribute appreciably to further progress.

The present era of high steam pressures and high temperatures, of rapid combustion and high rates of evaporation, has been made possible by the combined efforts of the technical engineer, the physicist, the metallurgist and the chemist. These men have first defined correct theory and have then translated that theory into sound practice.

By patient research, the properties of steam have been determined and reduced to simple tables. Laboratory apparatus and methods have been refined to a point where fuel analyses of surprising accuracy are easily and quickly obtained. Not only can the heat value of a fuel be determined, but the burning characteristics and fusing temperature of the ash may be ascertained so that the performance of a particular fuel in the furnace may be forecast. The chemistry of combustion has been expressed in understandable terms. The characteristics of metals have been investigated and values have been set which mark the limits of safe usage. The laws of heat transfer have been defined in rational formulas. The physicist and instrument designer have devised ingenious mechanical means for converting the intricate laws of pitot tube, weir and orifice flow, into simple gage readings. Feed water conditioning is receiving its share of scientific analysis and new cycles and new vapor media are being investigated and applied.

Thus, have science and engineering research widened the horizon of steam plant practice and made possible the gigantic units, the high pressures and temperatures, the enormous rates of evaporation and the excellent economies which characterize modern steam generation.

Wise indeed is the plant operator who familiarizes himself with these new tools which science has made available to him, for his advancement as an individual must surely lie in the same direction as the trend of progress in his field of work. Wise also is the executive who recognizes the value of research and who encourages its application as a means of raising existing standards.

An Achievement in Engineering Journalism

WE ARE living in an age when achievements of major character and importance are occurring with such rapidity that the spectacular is becoming almost commonplace. The limitations of yesterday are swept aside in the accomplishments of today. So fast is our pace that our very tempo blurs the path we travel, and we find it increasingly difficult to keep our perspective and to take full advantage of present knowledge and experience in working out the problems of the future.

In the matter of retaining perspective and balance, we have an invaluable aid in the technical press. The journals which keep us informed of all that is being accomplished in our various fields of activity, which periodically present us with a stock-taking of past achievement and an interpretation of present trends, are doing more in accelerating progress and enabling us to retain our appreciation of values in this period of flux, than any other single instrumentality.

A notable example of this high type of journalistic service is the April issue of Mechanical Engineering, commemorating the fiftieth anniversary of the American Society of Mechanical Engineers. Its authoritative presentation of the story of progress during the past half century in every major field of mechanical engineering will establish it as a valuable reference volume for many years to come.

As publishers, we have a keen appreciation of the tremendous task involved in producing such an issue and we congratulate the editors of Mechanical Engineering on a splendid journalistic achievement.

Trends in the Design of Coal Handling Systems

By H. S. FORD
R. H. Beaumont Company, Philadelphia

Fig. 1—A compact coal handling system which illustrates the point that simplification is secured when the coal cars can be brought directly alongside the plant

Methods of coal handling have not kept pace with the rapid development which has taken place in steam plant equipment generally. The author of this article faces the facts squarely in his discussion of this situation. He believes, however, that considerable progress is now being made in the direction of simplified design and more rugged equipment and that the results of this trend are being evidenced in many modern power stations in terms of reduced operating and maintenance costs per ton of coal conveyed.

THE decade following the war witnessed marked changes in practically every type of equipment comprising the power plant. Both electric and steam generating units have grown vastly larger and, consequently, fewer units are required per plant. Reliability has been built into these fewer units by improved design until now it is not considered poor practice to have many eggs in one basket. Many of the changes which have come about have been the direct result of enormous growth in demands for electrical energy as supplied by the public service corporations and as a consequence of this, the central station designers have been the pioneers in modernization. Paralleling the central station progress, however, has been an equally progressive tendency on the part of the manufacturing industries. As a matter of record, these industries have in some cases led the way in "trail blazing."

Despite the great tendency toward change, it is deplored by many engineers that development in coal handling systems and devices has not kept in step with the general trend. To a certain extent this belief is justified although I would say that there is a marked change in progress. For an appreciation of the situation, it is necessary to differentiate between "Coal Handling Systems" and "Coal Handling Devices."

During this progressive period which we are considering, there have been many meritorious improvements of devices such as application of roller bearings to belt conveyor idlers, hoists, transmission machinery, etc. But by and large, the *systems* are substantially unchanged.

This is probably because the average designer of a power plant has continued to consider the coal handling system as a necessary evil and to give thought to it only after everything else of major importance is settled, by which time it approaches the realm of an anti-climax and, the sooner disposed of the better. This, despite the fact that coal is the basic raw material of power production and that the cost of coal is still about 75 per cent of the operating cost in a modern coal-burning power plant.

Furthermore, the situation within the coal handling machinery industry itself has not been conducive to progress. There has been little, if any, real leadership within the industry. It requires very little capital to start in this business since it is essentially a contracting instead of a manufacturing business. The result is that there are today approximately thirty-five companies east of the Mississippi River claiming to be builders of coal handling machinery. Most of these are small local establishments, selling to a limited number of cus-

tomers and pretending to duplicate the most modern designs of the five or six national leaders. Low price is their principal argument and they obtain this low price—result of low overhead costs—at the sacrifice of breadth of experience and service, and intelligent design.

Inasmuch as the industry has been so much at the mercy of this local cut-throat competition, the logical leaders, have for the most part not only failed in any attempt at leadership, but have themselves to some extent, entered into the practice of copying any idea brought out by a competitor instead of sticking to their own knitting. Each large manufacturer has therefore been driven to a life of continued dependence upon repair order business, and, of course, the longer an idea lives and the older a device is in point of design, the better the repair business. Several manufacturers now have many of their devices on a production basis, so great is the replacement demand.

Despite the somewhat chaotic results of these conditions, there have been signs of increasing attention to progressive thought in designing and purchasing coal handling systems and it is logical

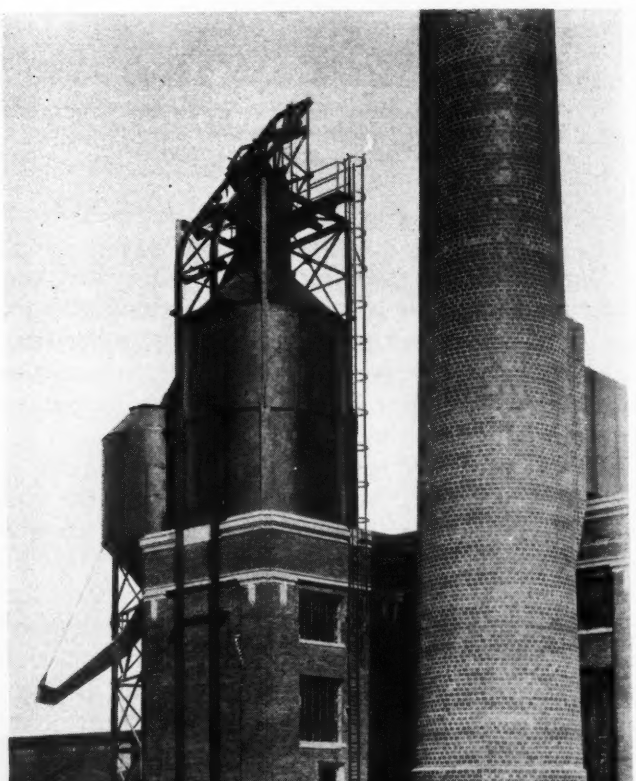


Fig. 2—A single skip hoist handles both coal and ash in this medium size plant

that the immediate results should parallel progress in other major items of power plant equipment such as fewer but more rugged units leading to simplicity and reduced maintenance.

A good "conveyor engineer" should try to eliminate conveyors and conveyor auxiliaries rather than find uses for additional ones. It is good design to go to much trouble and even to increase investment in fixed structures in order to eliminate a conveyor because the latter will be an item of daily operating expense during the entire lifetime of the plant, re-

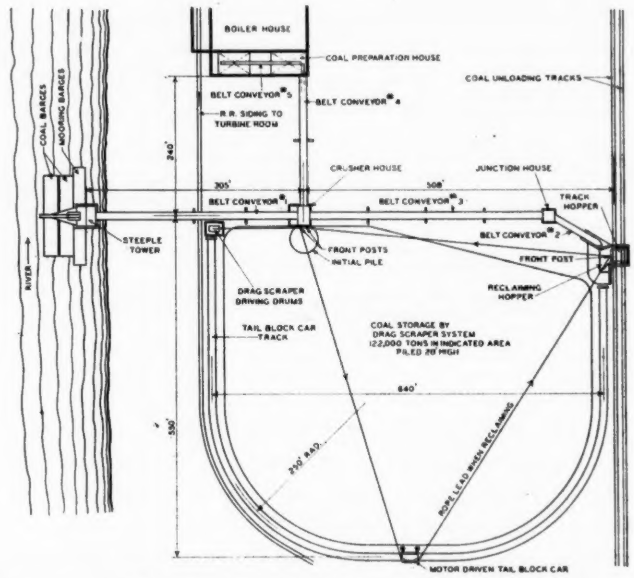


Fig. 3—A coal handling layout which could have been greatly simplified by provision for unloading the coal directly adjacent to the plant and by the use of direct elevating means

quiring power to run it, labor to operate and inspect it, material and labor to keep it in repair in addition to fixed charges on the capital invested, whereas structures have practically nothing but fixed charges.

Perhaps the most glaring and frequent example of this lack of simplification and elimination is that of a plant having its coal unloading siding several hundred feet away from the plant with nothing intervening but conveyors to take the coal from cars on the siding and deliver it to the plant. The coal cars have come perhaps several hundred miles from the mine and the switching cost of spotting them several hundred feet nearer the boiler plant would have been zero. And even if certain physical characteristics of the site might seem to make the capital investment on coal handling equipment less than if the siding were placed immediately adjacent to the plant, there is the inexorable item of daily operating cost and nuisance, probably overshadowing fixed charges. Don't forget also the possibility that the ground at first occupied by unnecessary conveyors may some day be vitally needed for some unforeseen factory expansion.

To illustrate this particular point, which I think is very important and not adequately realized by the average designer, I would draw attention to the accompanying illustration (Fig. 3) of a plant having facilities for receiving coal either by water or rail with the former greatly predominating. The axis of the main coal unloading system is located

240 ft. east of the boiler plant. It would seem to have made a far simpler plant if the steeple tower for unloading barges had been located just south of the coal preparation house and a single direct elevating device used to take the coal from the tower direct to a point over the bunkers. The railroad tracks could then have been swung around the power plant on a 90 deg. curve running just east of the coal house wall or additional sidings used paralleling the turbine room service track to deliver coal to this same elevating unit. The ground storage would have occupied approximately the same area but would have been closer to the plant. The conveying system as illustrated has proven entirely satisfactory during nearly five years' operation and no doubt this owner has little fault to find with the installation as a whole, but the alternate scheme suggested above would certainly have been simpler with fewer maintenance centers and with a consequent saving in labor of operation and inspection to say nothing of power, maintenance, and fixed charges. As it is, the plant appears as if the designers had a "conveyor complex."

An incidental disadvantage of this tendency to add conveyors instead of eliminate them is the resulting distribution of machinery over the entire system. There is an unconscious urge to put a crusher here, a screen there, a magnetic pulley and its tramp iron chute somewhere else. This gets away from compactness and simplicity and increases the time required to make adequate inspection. As much as possible of the actual moving machinery of a coal handling system should be concentrated in one locality in order to reduce maintenance labor and simplify inspection and repair as well as to confine dust and noise to narrow limits.

Several examples of this type of plant are shown here. Fig. 4 is a very good example, not only of how the coal handling system may be simplified as to units, but also how these units may be so consolidated as to reduce maintenance centers. Coal is unloaded by a steeple tower and fed directly to a primary breaking crusher (to pass a 4 in. screen) located in the steeple tower and from which it passes either directly to the elevating means (in this case a skip hoist) or to the initial pile of the ground storage. The skip hoist winding machine together with its automatic control equipment is also located within the steeple tower. A screen below the primary crusher makes it possible to send all fines (-1 in.) to the skip for immediate elevation to the bunker and the sized coal (-4 in. to + 1 in.) direct to ground storage. In the writer's opinion, this is an unnecessary refinement as the drag scraper method of storing coal gives a homogeneous mixture of fines and lumps reducing to an absolute minimum the

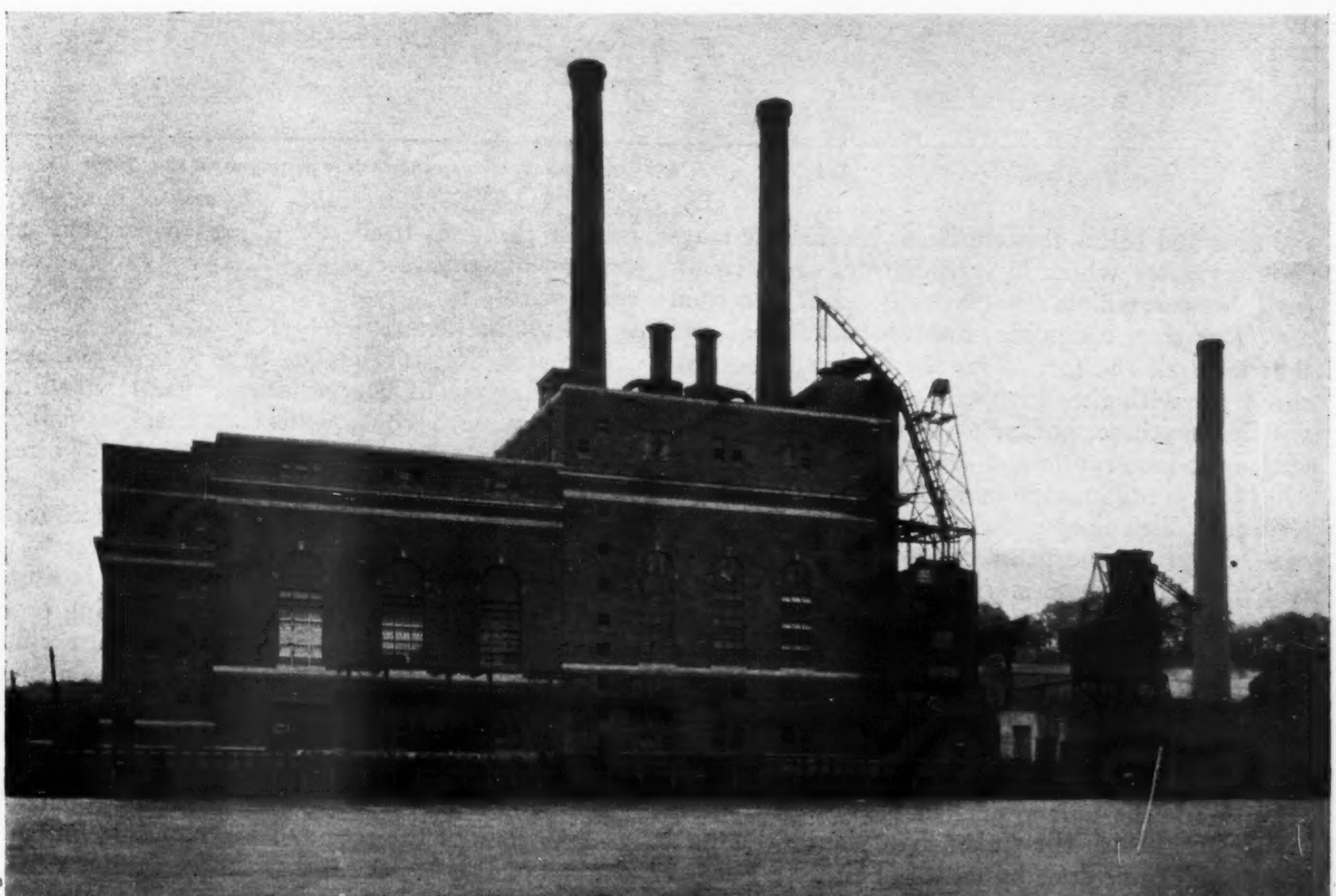


Fig. 4—The coal handling system for this large power station has few handling units and, consequently, a minimum number of maintenance centers

hazards of spontaneous combustion and weathering action. In other words, it is a fact that even run-of-mine bituminous coals can be stored with impunity by using a drag scraper. Especially is this true of the coal used at this plant which is best quality West Virginia.

But, to return to a description of this particular system, the coal, after it is elevated to the top of the boiler house by the skip hoist, is fed to a secondary or fine crusher capable of reducing it to ¾ in. and finer and below this crusher is located the magnetic separator which in turn delivers to an equalizing hopper which automatically loads the tram car. This tram car holds one skip bucket load and shuttles back and forth over the bunker being synchronized with the skip hoist and operated by its winding machine, and at this plant, is fitted with automatic integrating and recording scales, so that total coal going into the boiler house is weighed and recorded. This does not give a check on the total coal receipts at the plant because part of this coal is diverted to ground storage. Neither is it an instantaneous check on the boiler consumption as the contents of both the crushed coal bunker and the pulverized coal bunker will vary. However, there is, so far as I know, no reliable weighing device adapted to weighing pulverized coal just before it is fired in plants using the bin or storage firing system. With the unit system of pulverized coal installation as with the stoker fired plants, this final weighing can be done by means of either a larry or individual automatic scale.

It will be seen that this plant has two major maintenance centers, one in the steeple tower and one above the bunker, and some explanation may be in order. To locate all in the steeple tower would have required a much higher tower in addition to which there would have been no provision for crushing possible frozen coal from ground storage. Furthermore, the place for the magnetic separator is undoubtedly just before the coal makes its final drop into the bunker. On the other hand, to concentrate all the machinery items above the bunker would have required a tower superimposed on the roof, a thing in itself not objectionable, but not necessary in this case as there was available certain space within the steeple tower which would otherwise have been wasted.

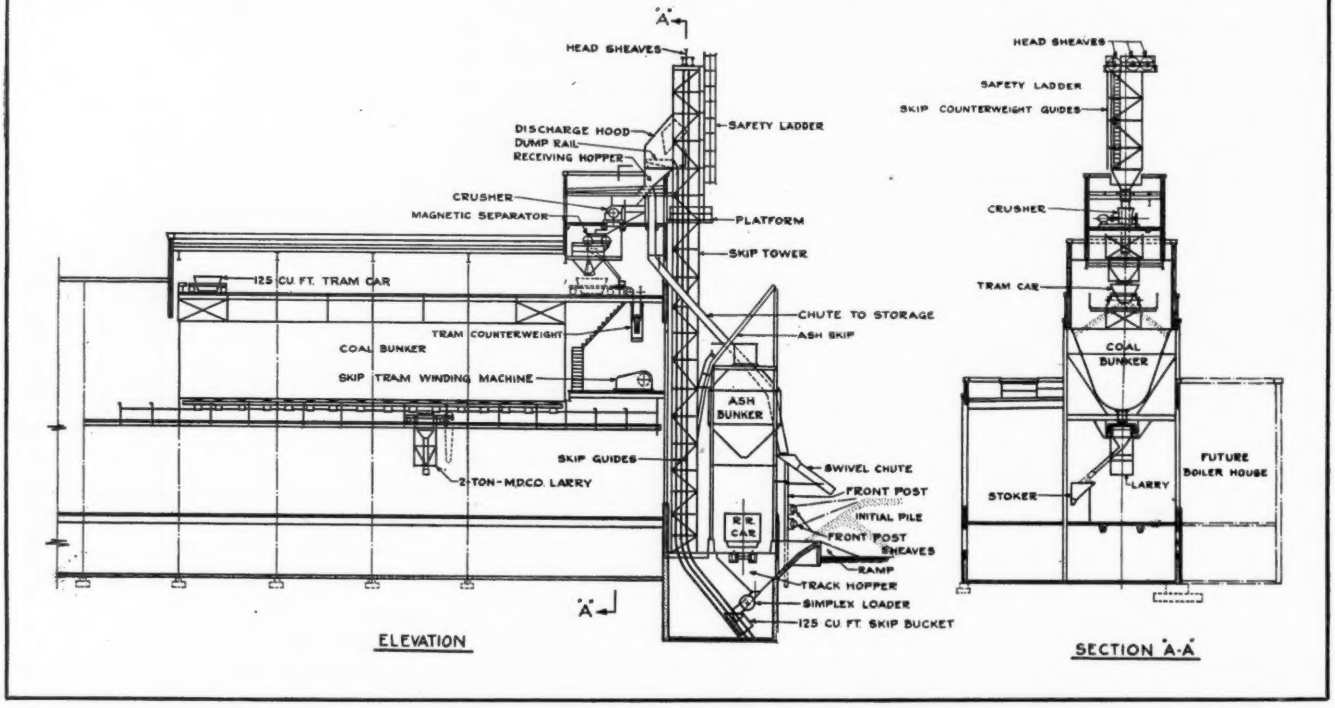


Fig. 5—Diagrammatic layout of plant shown in Fig. 1. Note the simplicity and compactness of arrangement throughout

The line drawing shown in Fig. 5 is an even better example of concentration of coal handling machinery with consequent reduction of maintenance centers. At this plant, coal is brought direct to the end of the boiler house in standard hopper bottom cars and discharged to a track hopper from whence the run-of-mine coal is elevated directly to the top of the boiler house where it feeds down through the crushing and magnetic separating processes to the distributing tram car. The skip hoist winding machine being located directly below the crusher room reduces to a minimum the spread between the different machines. In order to carry out this idea to the fullest extent, the ash skip hoist winding machine is also located within this same room. A general view of the coal and ash handling units at the end of this boiler plant is shown in Fig. 1.

It is obvious that dust prevention in a layout of this type is more nearly accomplished than it could possibly be in any system such as illustrated in

Fig. 3. This problem of dust prevention is very serious and should have careful consideration.

The simplifications treated of herein are not confined to the large boiler plant. Fig. 6 shows an exterior view of a small heating plant supplying a state normal school. In this case certain local conditions dictated that ash disposal be conducted from the end of the boiler plant opposite that at which coal is received. The coal handling equipment, however, shows extreme simplicity. A small daily supply bunker is located at one end of the firing aisle. It is filled directly by a skip hoist without the need of any distributing conveyor on top. The skip hoist gets its supply from a small hopper under the crusher which is located on the boiler room floor extension under the bunker. This crusher is fed by means of an apron feeder from the track hopper outside. A larry takes coal from the bunker to the stokers. Fig. 7 shows all moving parts of the complete coal handling machinery assembled in one small room which is an extension of the main firing aisle. This is truly a fine example of a

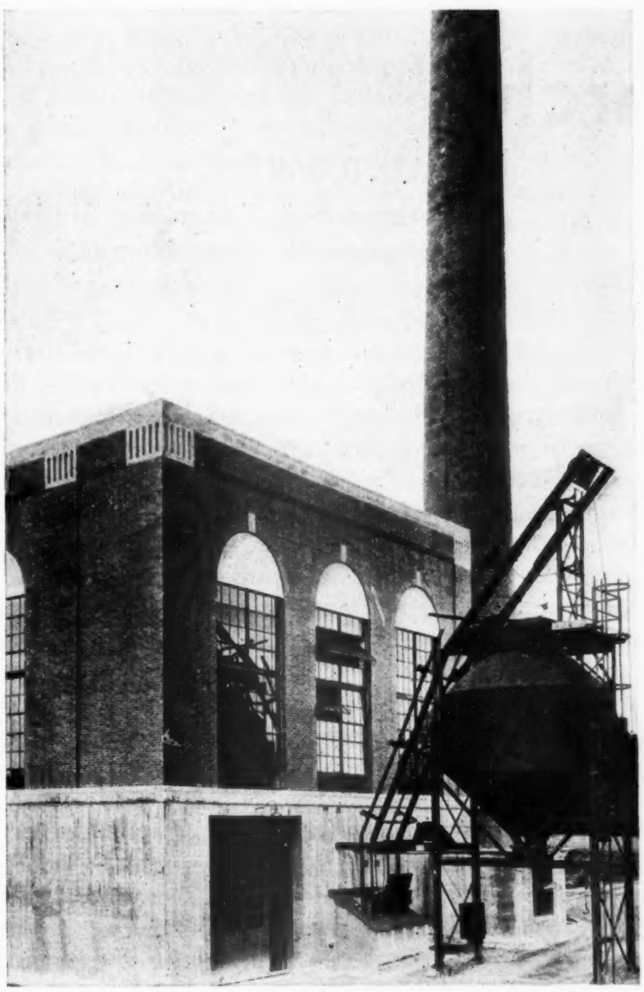


Fig. 6—A good example of a simple coal handling installation for a small plant

single maintenance center for a complete coal handling system.

Such plants as these strike the optimistic note and show what may be accomplished. One such plant reports over a seven year period maintenance figures varying from 3/10 cents per ton to 1 1/10 cents per ton of coal and ashes handled per year. And despite the extra ruggedness built into equip-

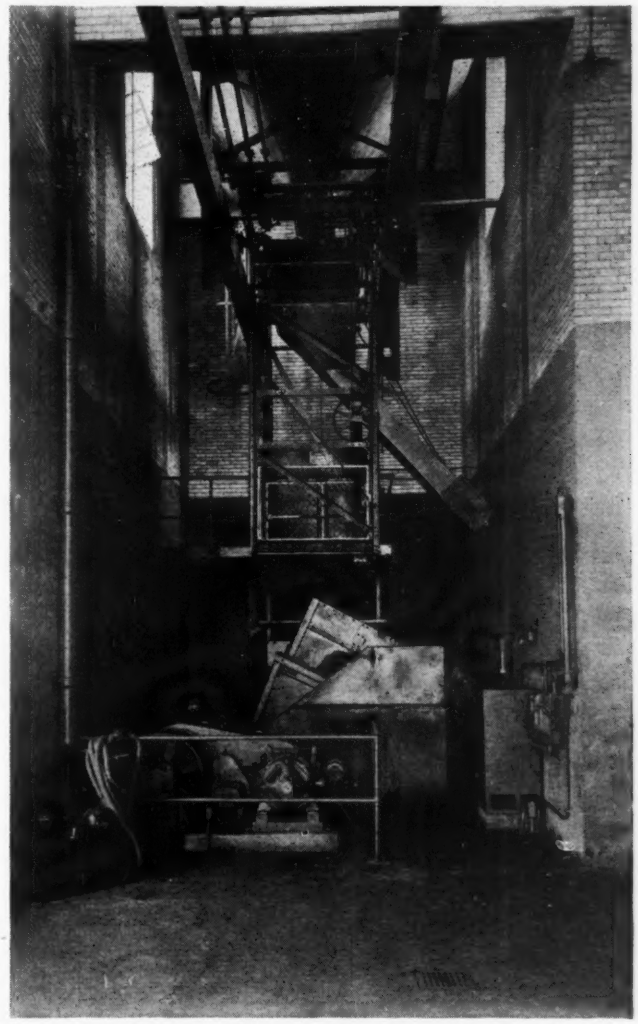
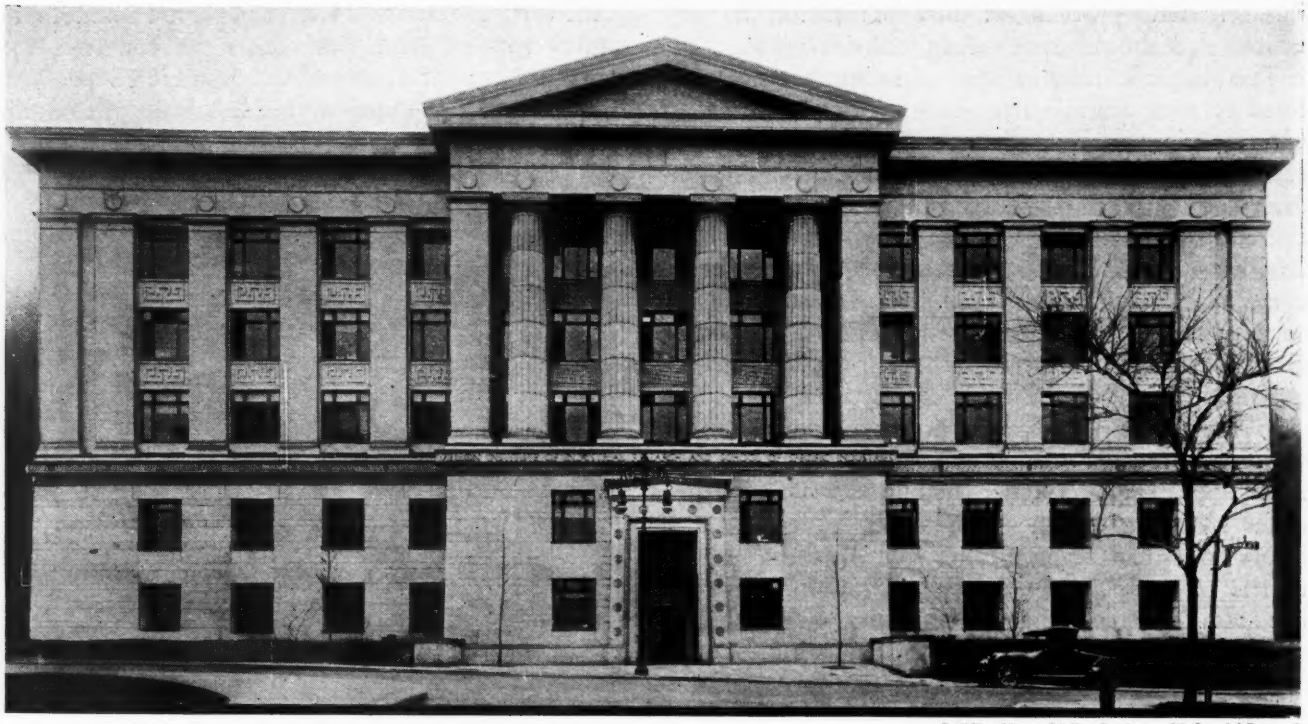


Fig. 7—Interior of plant shown in Fig. 6; concentration of coal handling units simplifies the work of inspection and lubrication and reduces maintenance and operating costs

ment of the nature mentioned, this same plant has total annual carrying charges (interest, depreciation, taxes and insurance) averaging about 7 cents per ton of material handled with the equipment operating at about 25 per cent of rated capacity.

The conculsion to be drawn is that while the simplifications pointed out here may lead to a few more rugged units which in themselves are more expensive than the many small parts distributed over a greater area, the fewer number required, combined with the usual savings in structures, and a very large saving in maintenance, combine in most cases to provide a lower carrying charge than would be possible with the more complicated layout.

It is therefore not very surprising that after all a definite trend is noticed toward this simpler more rugged type of coal handling plant and the type of buyer who is swinging to this kind of installation, while he is still in the minority, is the type whose leadership is most generally acknowledged and copied.



Building No. 1, Mellon Institute of Industrial Research

Engineering Research

By ALEX D. BAILEY
Superintendent, Generating Stations
Commonwealth Edison Company

Research is the stepping stone to industrial progress. The extent and rapidity of our progress in the future will largely depend upon the efficiency and scope of our research activities. Mr. Bailey, who is Chairman of the Engineering Section, N. E. L. A., and a member of the Main Research Committee of the A. S. M. E. and of the Utilities Research Commission, reviews the present situation with regard to Engineering Research in the United States, Canada, England and Germany. Apparently the great need in this country is for better organization of the widespread work that is being done by the principal engineering and trade associations, private corporations and other agencies. Such organization will result in economy, through the elimination of duplicate work, and will bring about more extensive and effective use of the fruits of our research endeavors.

"WHAT is not yet, may be," the inscription on the fiftieth anniversary medal of the American Society of Mechanical Engineers states a thought typical of engineering progress. Nothing is impossible; the mysterious becomes commonplace; that which is marveled at and unbelievable today is solved tomorrow and takes its place among the accepted things of life, while our attention turns to still other fields of investigation and exploration. Our country is fortunate, since in its early history it drew those who had the imagination, the ambition and the perseverance to attempt new fields and new methods of livelihood. That spirit has dominated American industry and may be in a large measure responsible for the heritage of research which is so characteristic of the American people. That, combined with our natural resources, makes an advantageous combination which has already accomplished wonders and promises more. The accomplishments of one generation are passed on to the next to be used as stepping stones to further explorations.

The eternal search for that which is new or mysterious or little understood is the basis of research. We may sometimes think that our great inventors are inspired or have a sixth sense, a special dispensation which enables them to accomplish where others fail and a super-human vision which enables them to penetrate the veil of mystery which surrounds those phenomena we do not understand. Invention is the result of research, which requires the everlasting continuity of imagination, ambition and perseverance. Accomplishment is the result of continued effort in whatever field we undertake; research is no exception.

We are told that the word research has been commercialized and cheapened by too common usage yet this serves only to emphasize the fact that we can

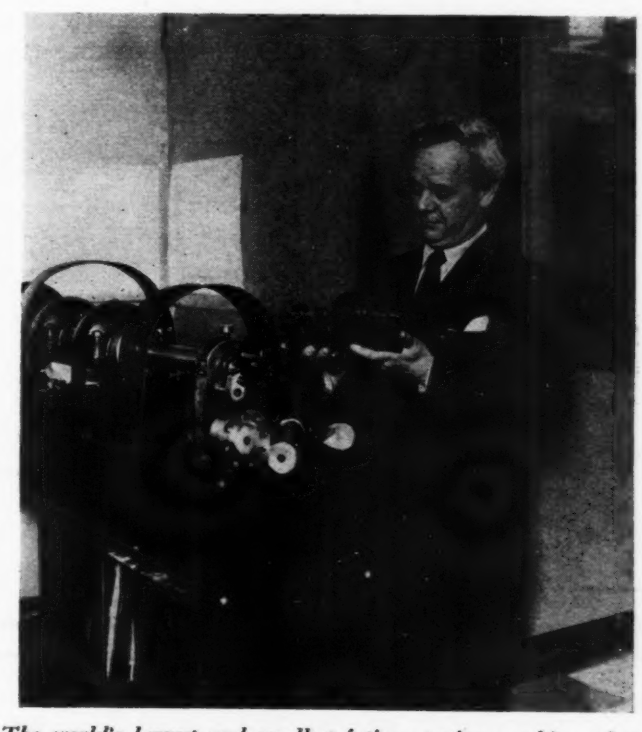
find no substitute which conveys the idea we wish to express. It is like the word "service" which is worked to death because we can find no other word or phrase to take its place. We cannot define the full meaning of the word yet we understand perfectly what it implies. In a facetious way there are fine distinctions sometimes made in the pronunciation of "research." With the accent on the first syllable, a general investigation of more or less common nature is implied, one relatively inexpensive; but when we wish to impress our listeners with the importance of an undertaking and give the impression that large sums of money are involved we put the accent on the last syllable. This may be fitting, as there may be a great deal of emphasis on the "search" for the money required.

By "engineering research" we mean that class of technical and scientific investigations which have a practical application to industry. Such investigations are generally directed at a specific object or center on some particular problem, and industry is continually setting up new problems. While such research in the past may have been considered a gamble, it has paid such prodigious dividends in the aggregate that it is now an essential part of any large, well-organized, progressive industry. As industrial organizations increase in size, and the value of their manufactured products increase, relatively small savings assume large proportions and larger and larger amounts can be economically spent to save a small percentage. The money which can be invested in research is consequently almost unlimited. This is one advantage of organized industry, as such amounts could not be considered in a small individual enterprise. The inventor working alone in his shop has been succeeded by the trained research expert working in a well equipped laboratory, with almost unlimited funds at his command, and by specialists with all the apparatus, instruments, and devices to do a good, thorough job. Invention is the result of research, and organized research must be the order of the day in our highly organized industrial development.

Research has been given an added impetus since the war not only here but in foreign countries as well and each nation is attempting some organization of its research activities, generally along different lines. In some cases industrial research has been encouraged and partially supported by the government, in others it is left entirely to the industries themselves to organize through their engineering societies or industrial associations. In other instances it has been a combination of the two. The agencies and personnel for the work are different in different cases depending largely on the viewpoint of the group or organization sponsoring the research.

In Canada, the province of Ontario has taken a very forward step in the formation of the Ontario Research Foundation, a government organization which will cooperate with industries in conducting research of general interest. This is described at length by H. B. Speakman, Director, in the University of Toronto Monthly for February, 1930. Under the plan established, the government will put up an amount of money equal to that raised by an industry to conduct pertinent research. The Foundation will provide the laboratory and facilities for conducting research and to this end is preparing facilities for joint research with the Ontario Metal Industries Research Association composed of the metal industries of the province. While some of the larger industries with funds sufficiently large will doubtless continue their industrial research departments, the smaller manufacturers who cannot support such industrial projects will, as soon as they have sufficient faith in the value of research and sufficient confidence in each other, cooperate in the study of mutual problems which they as a body can undertake. Our friends in Canada have realized that there is no more fruitful field for cooperation than in research and that the day of the individualistic attitude is passing.

This organization is somewhat like the organizations which have grown up in England since the war. There a group of companies or individuals engaged in the same industry join together to form an association to which they give financial support. The government on its part through the Department of Scientific and Industrial Research has contributed



The world's largest and smallest fatigue testing machines photographed in the laboratory of the Westinghouse Electric & Manufacturing Company. The smallest tests a specimen 0.05 in. in dia. and the largest 2.25 in. in dia.

under certain conditions an amount equal to that raised by the association. The members direct the work through an appointed council and the reports of the work are distributed to members only. Later

they may be published and made available to anyone.

Some of the early recommendations for coordinated research in England specified that the work should be done at universities and that these institutions should be organized so that men in the post graduate field would be trained for this type of work. This would stimulate the interest of the students along the lines of research and would tend to develop a group of highly trained, research-minded experts. It was pointed out that if these men were guided in their work by men in the industrial field who were acquainted with the practical requirements, a very effective combination would be accomplished.

J. M. Spitzglass in a recent paper prepared for the American Society of Mechanical Engineers, entitled "Research in Germany" gives a very clear picture of conditions in that country and emphasizes the advantages of cooperative research work. The outstanding feature of engineering research work in Germany is the correlation of such activities with the main engineering societies. The Verein Deutscher Ingenieure in Berlin coordinates and controls practically all the research activities of the engineering profession and acts as a clearing house for all the work of an engineering nature done by the state, government or scientific institutions. The scope of its work includes both industrial and scientific branches of engineering. Such an arrangement eliminates, first of all, the possibility of duplication of effort in research work and secondly, lends to each item the backing of the profession throughout the

Installation in one of the semi-commercial laboratories of Arthur D. Little, Inc.

country. Publication by the Verein Deutscher Ingenieure carries with it sufficient authority for widespread utilization of the results obtained by research.

Another feature of German industrial life which tends to disseminate general information is the organization of industrial exhibits all over the country. These are fostered by the state or municipality and are intended to show what has been accomplished in any given line of industry. As against these two highly cooperative endeavors, we still have remnants of the old-time reticence of one manufacturer to share his trade secrets or details of manufacture with a competitor. It seems, however, that with the in-

Materials sampling room, Pittsburgh Testing Laboratory

fluence of these two cooperative endeavors, this jealous guarding of personal trade secrets will diminish in importance. The fact that some of the larger industrial organizations issue periodically bulletins describing research activities of a general nature and of general interest is probably the best indication of the trend toward general dissemination of information.

A great part of the research work done in Germany is assigned to the technical universities where post graduate men are trained and used for this purpose. This has a great advantage since it affords excellent training for the men in the universities and gives an opportunity for those who are research-minded to show their ability and become expert at this line of work. The universities are stronger for their contact with practical work and the industries profit since a corps of research experts, who are undergoing continual training, are available for almost any job that may be presented. The V.D.I. being in touch with the equipment and personnel of these institutions as well as other agencies knows at once where a certain piece of research can be handled to advantage. The fact that the society acts as a clearing house for research work enables it to keep up to date on whatever is being done.

To get a picture of the status of industrial research in our own country we can quote from the 1927 report of the American Society of Mechanical Engineers on Research Activities; "According to information recently collected by the National Industrial Conference Board, incidental to a study of industrial organization, about two hundred million dollars is spent annually, by corporations and the government for in-

dustrial research. Industries whose research expenditures were largest five years ago are those which have scored the greatest growth since then. So rapid has been the extension of research work that whereas in 1921 only five hundred and seventy-eight companies were known to maintain research departments or laboratories, more than one thousand concerns have organized research divisions in operation at the present time." There is of course no method of accurately determining the amount of research actively going on because of the necessarily secret nature of much of that carried on in the laboratories of our large industrial organizations but it is safe to assume that the amount and extent of industrial research have very materially increased since this report was written.

All this is entirely independent of research supported by the various foundations for Medical Science or similar projects and of the recent endowment sponsored by the National Academy of Sciences which is raising a national fund for the support of research in pure science. The booklet prepared by this organization, descriptive of the aims of the venture, gives an outline of this laudable work which is being supported by the industries of the nation. The importance of these scientific researches can not be overestimated.

Our engineering research is conducted in a multiplicity of ways and under a multitude of conditions. Large industrial organizations generally have their own research staffs engaged on work of a local or special and sometimes secret nature either in their own laboratories, at the laboratories of the universities or at some other agency. Little or nothing may be known by the country at large of research of this kind. In other cases, we find associations of industries, particularly in the non-competitive field, directing or coordinating research in their respective groups. This may be carried on at universities, in coordination with government agencies or in private laboratories. This information, however, is generally available to the industry and the public quite promptly. We then have the research work which is being conducted under the direction of the engineering societies, some of which is done in industrial laboratories, some in connection with government institutions and some in universities. The sponsoring of a research activity by one of our engineering societies gives it the backing and authority which is generally necessary if funds are to be raised and to insure it the recognition it deserves after it has been completed.

While the money spent may be a small percentage of the income from our industries, it is very evident that it has reached rather gigantic proportions and if we are to learn from our past experience in the development of large industrial organizations we should organize in such a way that duplication of effort will be avoided, so that we will get the greatest value for every dollar spent and so that the results of this work

A Room in the Research Laboratory of the General Electric Company

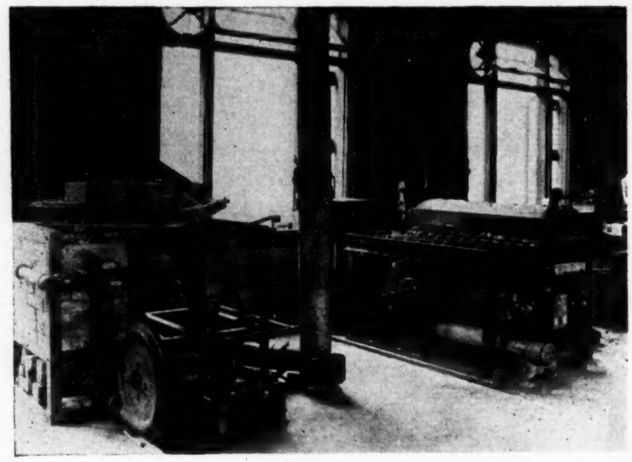
will be generally available so far as possible. The National Research Council directs and coordinates engineering and scientific research of general interest while numerous other agencies play an important part in the research activities of the country. So much work is being done along this line that there seems to be plenty for all to do.

Our national Engineering Societies can and do perform an important part in certain lines of research. The American Society of Mechanical Engineers, which is probably the most active in this field, has twenty-seven projects of a general nature which it is sponsoring now. Others devote a more or less substantial part of their dues to a research fund and the Heating and Ventilating Engineers have a laboratory and an organization for carrying on their own research. A study of the last report of the National Research Council shows that there are twenty-two technical and scientific organizations in the United States which encourage and foster research of one kind or another by giving medals, raising funds, or actually directing the work.

Referring again to the American Society of Mechanical Engineers' publication on Research Activities, the advantages of conducting research matters in this manner are well described. "By virtue of its purpose as an association of engineers organized for the advancement of mechanical engineering, its allied arts, and the good of mankind, The American Society of Mechanical Engineers should very properly take the lead in the promotion and fostering of research in mechanical engineering in this country. Unlike the trade associations, whose research activities are confined to a single industry and the

Partial View of research laboratory of the Bakelite Corporation

problems of that industry, this Society embraces the whole field of mechanical engineering and consequently its broader and more fundamental problems while the trained personnel of its membership peculiarly fits it to undertake such work. To enumerate, the following important functions may be exercised:



Furnaces used in investigations on refractory materials at the Mellon Institute

(a) Act as a clearing house for the dissemination of research information.

(b) Coordinate existing research work where possible, thus eliminating waste due to the duplication of effort.

(c) Support existing research where advisable.

(d) Organize and conduct cooperative research work on problems of both a fundamental and applied nature in engineering and industry.

(e) Develop ways and means of assisting in the education and training of research workers for industry."

In the field of industrial associations, the American Railway Association is a fine example of an industrial organization which has organized its research activities along business-like lines for the general good of the industry it represents. This Association is reported to have spent as much as two million dollars per year on research, a single item involving an annual expenditure of one quarter of a million dollars. Another is the American Gas Association which has also had its research activities well organized for some time past. This organization has a research laboratory at Cleveland which, working by itself or in conjunction with universities or other agencies, directs and coordinates the research work of the industry, particularly on problems of general interest. The National Electric Light Association has recently organized a research committee in the Engineering Section with a Secretary at Headquarters. The function of this group will be to direct work of a general nature and administer funds if necessary, to keep in touch with research work both in the industries represented and in associated industries and, in general, to coordinate the research work of the operating companies in the association.

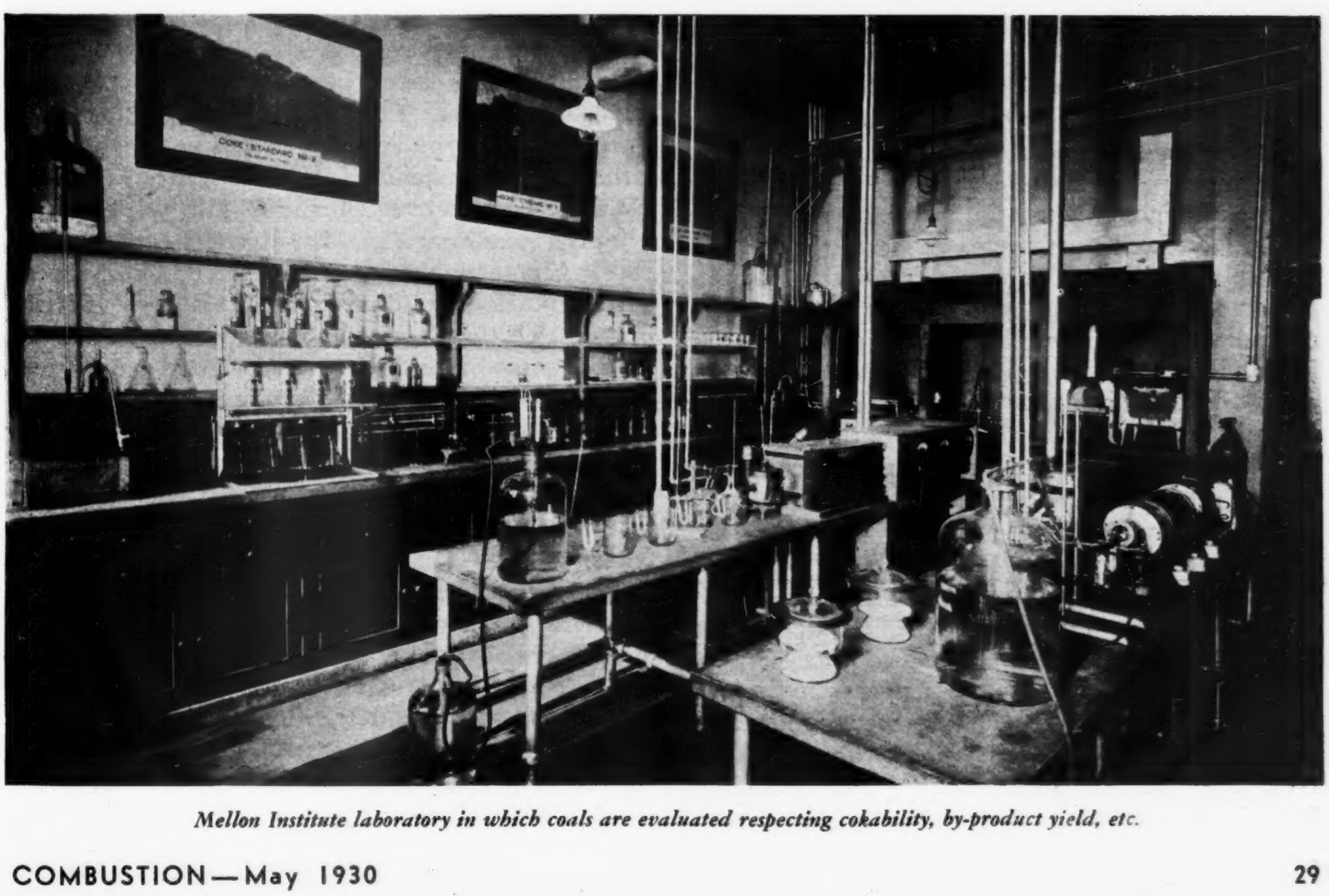
These are but a few of the industrial research organizations already underway. In the industries represented the money spent for research should be

utilized to the best advantage whether the associations handle the research directly or whether it is conducted by individual units of the associations.

With industries spending literally millions of dollars annually in research it is evident that proper organization of research activities will save large amounts of time and money. We are reputed to be a country of organizers and are alleged to have more societies and associations covering more different kinds of activities than any people in the world. If this be true, some of our "joining" ability should be exercised in organizing the engineering research of the country by industries, which is a logical division, or along some other lines so that the work may be coordinated, so that those doing it will be properly informed and so that the work will be efficiently and economically performed without duplication and lost time. Each group of industries will then have a clearing house for information on research where those who are interested and entitled to such information can find out the latest developments. That work which is of more general interest or application can be handled by the engineering societies, as it now is, to the best advantage. The engineering societies might even act as clearing houses for information supplied by the trade organizations. By thus keeping in touch with the work being done and the facilities and personnel, these societies would be in a fine position to give advice regarding the disposition of contemplated research work. The possibilities are almost unlimited.

The importance of trained research men must not be lost sight of. Sufficient work should be delegated to the engineering universities to encourage the application and training of those who are research-minded and have the proper qualifications for work of this kind. The closer the industries and the universities can collaborate on this program the better it will be for both, as each will learn from the other and gradually there will be built up a corps of trained research experts ready to intelligently tackle any problem which industry may put up to them. Though these men may be later taken over by the industries in one position or another, a suitable supply from which to draw such men will be provided.

Engineering Research has become one of the most important activities of our industrial organization and the money spent annually has reached such proportions that some effort should be made to organize and coordinate the various lines of activity to the end that it may be conducted as efficiently and economically as any other branch of our industrial organization. Here lies another opportunity for showing organizing ability. In other countries research has not only been organized but in some cases is being subsidized by the governments. While this may not fit in with our way of thinking, it is evident that we must give consideration to industrial conditons in other countries and must be prepared to meet them; we should at least profit by their experience. If, as claimed, research is one of the most important factors in our industrial development, its organization and coordination deserve and must have our prompt and earnest consideration.



Mellon Institute laboratory in which coals are evaluated respecting cokability, by-product yield, etc.

Economies in the Generation and Distribution of Power*

By W. A. SHOUDY
Consulting Engineer, New York

The economy resulting from interconnection of power lines is perhaps the basic reason for the many consolidations that have taken place in the public utility field. While these economies cannot always be accurately predetermined, experience has shown that where load conditions of adjacent stations appear to justify interconnection, either through consolidation or cooperation, the resultant savings are invariably substantial. The author analyzes this question in a particularly able and interesting manner. He also reviews the progress made in power generation and in operating efficiency.

IN the early days of the electrical industry, high transmission costs made it necessary to locate power stations as near as possible to the points of consumption. With the great progress made in reducing distribution costs, this situation has undergone a material change, and, today, the question of plant location is largely determined by the factors of water and fuel supply.

Low cost transmission has made it possible for the electric utilities to lead the way in effecting economies by means of consolidations. These consolidations have sometimes been corporate, and in other cases, the benefits of consolidation have been obtained by cooperation. In this way the most economical plant has been assigned the larger part of the production, and in many cases inefficient plants have been shut down. It is exactly the same principle that assigns to the lowest cost steel mills, the greatest production, and slows down the inefficient ones. By cooperation between power companies, similar economies have been effected, very much as if one steel company filled some of its orders for rails by buying them from another company, except that in the case of the power companies earnest attempts have been made to equitably distribute the profits.

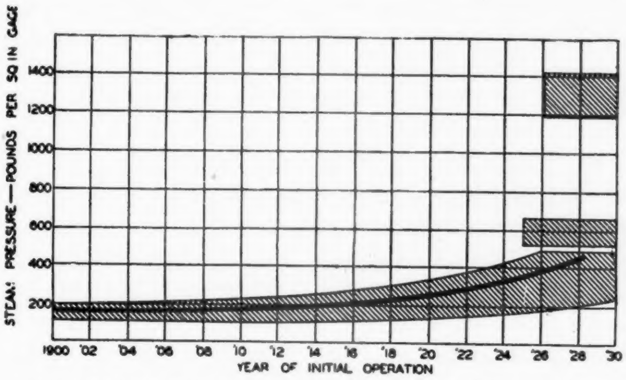
It is unnecessary to discuss in detail, the advantages of operating the most efficient plants for the greatest possible hours per year, provided those plants are owned by the same company. There seems to be, however, some misinformation as to what can be done by cooperation between unrelated companies whose properties are separated by but relatively small distances. There is not much opportunity for interchange of power between companies serving the same type of district. For example, the combined load curve of all the companies in New York City is substantially the same in form as that of Newark, N. J. They are both largely residential and manufacturing districts, with some power used for street railways. The consequence is that the peak loads occur at substantially the same times in both districts and when one company has spare capacity, the other also has an abundance.

There is, however, quite a marked difference between conditions in New Jersey and eastern Pennsylvania. There is a considerable mining load in most of Pennsylvania, resulting in a peak on the system at or about 10 o'clock in the morning. The consequence is that when eastern Pennsylvania is heavily loaded, the companies of New Jersey or Philadelphia are operating at a relatively lighter load, but when the afternoon or evening peak occurs in New Jersey or Philadelphia, eastern Pennsylvania loads are relatively light. There is consequently spare capacity available and for sale in New Jersey. Therefore, we find Philadelphia, eastern Pennsylvania and New Jersey are physically tied together by transmission lines and operating in complete harmony, though at present there is little possibility of substantial interchange between New York City and New Jersey.

The generating cost of all of the larger steam electric systems is so nearly equal that without diversity of load, there is little reason for interconnection and interchange of power, but if some other nearby system shows a diversity with one or the other, there is a real possibility of economy through interconnection. The diversity between New York City and New Jersey is small, but between either location and Pennsylvania it is large. It is not improbable that Pennsylvania may help New York or vice versa. This does not mean that Pennsylvania power will be transmitted to New York, but that New Jersey power may be diverted to New York and Pennsylvania supply New Jersey's deficiency. In this way Adirondack water power when abundant has been substituted for steam power in Pennsylvania, not by long distance transmission, but by successive displacement of load, and Pennsylvania has furnished steam power to northern New York during periods of dry weather. Such displacement of load has greatly reduced the necessity of spare equipment. We build stations without spare turbines, and often without spare boilers, because somewhere in a neighboring system is an older plant that can be depended upon in an emergency.

*Abstract of paper presented before the A. S. M. E. of Allentown, Penna., January 21, 1930.

We cannot overlook the importance of hydro-electric power when operating with a steam system; in fact, we cannot intelligently discuss the subject except as it is related to steam power. Although the operating cost of hydro-electric power is low, the total cost, including fixed charges, is frequently



(Shaded areas indicate approximate limits of central-station practice.)

Fig. 1—Increase in steam pressures; chart reproduced from paper by C. F. Hirshfeld.

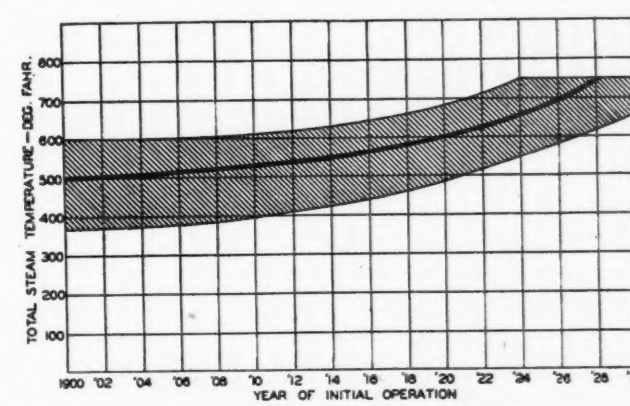
very high. This is because the cost of installation is usually two to three times that of steam power installations. If the stream flow is regular, the hydro plant can be operated at high load factor; then the total cost, including fixed charges is low and it becomes an active competitor of steam power. If on the other hand, stream flow is extremely irregular, the total cost of power may be such that investment in the plant is not justified.

There are very few streams in this country whose flow is so regular that a hydro-electric installation can be made to operate at high load factor, unless this plant is designed for minimum stream flow or for average flow with very large pondage or reservoir which greatly increases the investment. Hydro-electric power during periods of high stream flow has been made extremely valuable as an adjunct to a steam electric system, by carrying the peak requirements of the system and permitting the steam plants to operate at a uniform load—in other words, the hydro-electric plant becomes a storage battery floating on the line. Under such conditions, a steam generating plant can be operated at an efficiency approaching test conditions and this alone may mean a very large financial saving.

The cost of variation in load on the steam power plant is a serious loss that all recognize. In the writer's opinion it means a loss of at least 5 per cent and maybe 10 per cent. It is not only because variable load means carrying of banked fires, but because variation requires constant and most active supervision of the fires. Automatic combustion control has done much towards eliminating this waste, but even with the most perfect control, it is obvious that test conditions are not obtained, and we know by experience that a uniform load gives us the highest boiler efficiencies. Interchange of power tends to smooth out the irregularities in plant load and results in savings which cannot be forecast, but which are always substantial.

To state accurately in dollars and cents the economies due to interconnection of power stations is impossible. This is not because figures are unavailable, but because it is so difficult to properly apportion costs. That there is a substantial profit is evidenced by the fact that new inter-connections are being made almost daily. The answer is found of course in the annual balance sheet, but so many other factors enter into this balance sheet that it is difficult to analyze it. It is just as accurate to figure in advance the economies, for insofar as the writer has been able to find out, such interconnections when intelligently planned have resulted in profit to all concerned. As an example of what has been done, one company was able to sell dump peak power, if, as, and when delivered to its neighboring companies for a total amount equal to one-half of its net income, and the neighboring companies made an equal profit in actual dollars.

An estimate of future savings based upon average monthly costs of power to plants is of little value. Occasionally, one company can sell to another, power at such a cost as to permit the second company to completely shut down one of its plants. The estimate of savings is, in such a case, based upon a comparison of the annual cost of power, with the cost of purchased power. In other cases the basis for decision becomes, not the cost per kw. hr. over the month, but the incremental cost, due to the addition or subtraction of load to a plant already running. When power costs are analyzed from this standpoint, it is sometimes found that the incremental cost of additional load on a steam plant is



(Shaded areas indicate approximate limits of central-station practice.)

Fig. 2—Increase in total steam temperature; chart reproduced from paper by C. F. Hirshfeld.

less than the dump power cost from some hydro-electric plants. Such an analysis is shown in Fig. 3. Monthly operating costs of the two plants are respectively: Plant A—4.4 mills per kw. hr. Plant B—4.28 mills per kw. hr. Plant A consists of two turbines of the same size. Plant B consists of three turbines of varying size. The result is that though plant A's cost is slightly higher than plant B, when measured over the month, there are periods when

plant A's costs are less than those of plant B. These costs are best shown by plotting the total generating cost in dollars per hour against load on the plant. The resulting curve for A is made up of two slightly convex lines, and for B, three such lines, the uppermost line being markedly convex, and indicating that at these loads, a less efficient turbine is operating.

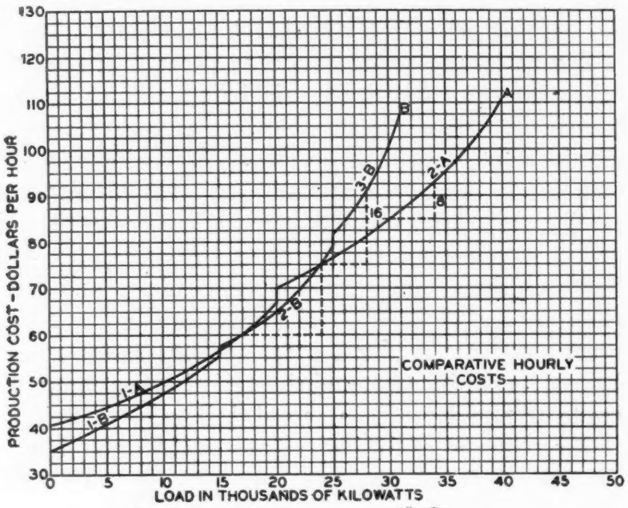


Fig. 3—Comparison of generating costs

Assume for example, that there is a load of 24,000 kw. being carried by plant B and 30,000 by plant A. An additional load of 4,000 kw. is expected by plant B. It would be necessary therefore to start up the third unit. The cost of this additional 4,000 kw. if generated by plant B would be $16.00 per hour, or an increment cost of 4 mills per kw. hr. If that additional load is carried by plant A, it will be added to the two turbines so as to bring the load up to about the most economical point for operation. The consequence is that the additional power can be generated at plant A for $8.00 per hour, or 2 mills per kw. hr. Assuming that these two plants are owned by separate companies, there will be a profit of $8.00 per hour which might be equally divided between the two companies.

For an accurate comparison, the costs should be figured at the point of juncture of the two systems to include transmission losses rather than at the switchboard, but since these points of juncture may vary, particularly if there is more than one point of connection, the cost at the switchboard is sufficiently conclusive.

When operating costs are compared on this basis quite frequently very surprising results are discovered because the total hourly cost line is never a straight line. Savings by interchange are not large when a system is made up of units of similar economy, but most systems comprise a variety of sizes and types of units. Quite frequently, therefore, a 50,000 kw. unit may be loaded up in one system by shutting down a 10,000 kw. in another, each company sharing in the saving. The total savings per year, depend of course upon how many hours such interchanges can exist.

Inasmuch as power companies are generally not in competition with each other, it is possible for them to exchange cost data; consequently, contracts are unnecessary. If an operator has excess power for sale, he will sell it if his price is right, and he won't sell it if he asks too much profit. I know of one contract broken five times the first two days of operation. In the present state of the art, we cannot look ahead far enough to write into contract form, the various situations that will arise in interconnection.

Engineers have a source of considerable just pride in the developments in the manufacturing department of the power companies within the last thirty years. These developments have been startling, for although relatively small improvements have been made from year to year, the fuel consumption per kilowatt hour has been rapidly reduced. Thirty years ago we required about four times as much fuel per kw. hr. as we do today. Without a very careful study of the records for the last thirty years, one would be inclined to say that these improvements have been due to rather radical steps. Fortunately, there has been published, within the last few months, sufficient material to make such an analysis, and we find that the improvement has been gradual with very few radical steps, most of the economy being due to painstaking attention to minor details.

It is of course, impossible to state the exact situation for any one year. Steam pressures, temperatures, size of boilers, generating units vary even today. A very fair indication of the gradual trend in steam pressures and temperatures was given by C. F. Hirshfeld in an address before the Society for the Promotion of Engineering Education, published in Mechanical Engineering, October 1929. These trends are shown in Figs. 1 and 2. Today, pressures of 450 lb. and temperatures of 750 deg. fahr. are not uncommon, and there are some plants exceeding 1000 lb. and 750 deg.

This increase in pressure and temperature, of course, has had much to do with the improvement, for it has increased the efficiency of the cycle, but the improvement must also be credited to improved turbine design and improved boiler and furnace conditions. The increase in size of boiler units, has, of course, been of considerable help in improving boiler efficiency, but an analysis of boiler tests indicates that the major improvement has been due to watching just two items in the boiler heat balance, namely: excess air and carbon loss. Although the improvement in efficiency has been reasonably regular, reports of boiler tests show only two major improvements. First, about 1911, tests by Jacobus at the Del Ray Station, show that 80.28 per cent boiler and furnace efficiency was possible with the underfeed stoker. The next step was indicated in a report of tests at the Oneida Street plant, Milwaukee by Kreisinger & Blizard, showing that 81.6 per

TABLE I

Results of tests conducted at various stations in the period from 1900 to 1928. These tests reflect the general trend of boiler and furnace efficiencies over the period. Except for the tests by Jacobus in 1911, by Kreisinger and Blizard in 1921 and by Wolff in 1924, which represent relatively large increments of advancement, these results indicate a fairly gradual improvement.

ITEMS	OHIO STATE UNIV. TESTS BY -HITCHCOCK 1901 - 02		DEL RAY STA. TESTS BY - JACOBUS 1911		ONEIDA ST. STATION TESTS BY - KREISINGER & BLIZARD 1921		CONNORS CREEK TESTS BY - THOMPSON 1921		COLFAX STATION TESTS BY-C.W.E.CLARKE 1923		AMSTERDAM STATION TESTS BY - W.A.SHOUDY R.C.DENNY 1923	
TYPE	HAND FIRED		TAYLOR STOKER		PULV. FUEL		TAYLOR STOKER		WESTINGHOUSE STOKER		COKE STOKER	
RATING PERCENT	157%	165%	107.9%	162.8%	112.4%	167.4%	153.3%	225%	175%	176.8%	161%	177.4%
DATE OF TEST	Feb. 23 1901	March 5 1902	June 3-21	June 5-7	?	?	April 7 to Aug.6		July 30	July 19	Aug.22	Sept.26
NAME	No.106	No.163	No.8	No.9	No.33	No.30	No.21	No.23	No.8	No.9	No.9	No.5
HEATING SURFACE - SQ.FT.												
BOILER	1070	1070	23,654	23,654	4620	4620	23,654	23,654	22,914	22,914	13,450	13,450
WATER WALLS	-	-	-	-	48	-	-	-	-	-	-	-
SUPERHEATER	None	None	Yes	Yes	594	594	2,996	2,996	2,999	2,999	3,863	3,863
ECONOMIZER	Not Used	Not Used	None	None	None	None	None	None				
AIR HEATER	Not Used	Not Used	None	None	None	None	None	None	Not Used	In Use	None	None
E.B. PER $ BOILER S.	5,260	6,528	3,730	5,454	3,765	5,608	5,135	7,537	5,862	5,923	5,393	5,943
GRATE AREA	25	25	405	405					218.3	218.3	364	364
TEMPERATURE - FEED WATER	52.5°	52°	181°	184°	100°	99°			115.8°	116.6°	145°	152°
TEMP. GAS - FINAL EXIT	603°	702°	493°	574°	472°	610°	572°	690°	437°	323°	536°	508°
PERCENT $C.O._2$ BOILER EX.	11.88	11.38	13.69	14.74	15.80	15.40			11.13	12.40	11.58	13.14
APPROXIMATE PERCENT EXCESS AIR	50.39	73.90	32.0	22.8	15.0	18.0			59.69	47.54	54.6	37.4
COAL - KIND	POCAHONTAS LUMP	HACKERS RUN W.VA.	BITUMINOUS		ILLINOIS		W.VA. MINGO	W.VA.	HARWICK RUN OF MINE		ANTHRACITE NO.3 BUCK	
MOISTURE	0.95	0.85	1.91	2.12	3.07	2.75			3.72	4.16	10.68	9.69
CARBON	87.75	72.05	77.19	77.64			75.83	75.83	73.51	76.10	78.42	76.55
HYDROGEN	4.34	5.00	5.33	5.22			5.08	5.08	5.04	4.61	2.47	2.61
SULPHUR	0.61	3.80	1.26	1.08	2.66	3.49	1.03	1.03	1.20	1.25	0.72	0.34
NITROGEN	0.88	1.00	1.12	1.05			1.25	1.25	1.32	1.15	0.85	0.46
OXYGEN	2.93	7.40	9.05	7.74			9.06	9.06	6.00	5.76	2.78	2.49
ASH	3.49	10.75	6.05	7.27	11.63	13.72	7.75	7.75	12.93	11.13	14.76	17.55
B.T.U. PER LB. - DRY	15.196	13.764	13,965	13.998			13.927	13.927	13.225	13.515	12.310	12.470
" " " AS FIRED	15.053	13.647			12.178	11.875	13.280	13.330	12.733	12.953		
HEAT BALANCE - PERCENT												
ABSORBED BY BOILER & AC.	67.2	61.33	80.28	77.85	81.60	78.80	78.30	78.10	76.00	84.13	73.20	76.70
LOSS - DRY FLUE GAS	15.4	17.05	10.12	11.21	8.60	11.40	13.10	13.10	11.71	7.08	14.50	11.84
" MOISTURE IN COAL	(	(	0.17	0.20	0.30	0.30	0.40	0.30	0.37	0.40	(1.10	(0.97
" " " AIR	(	(	0.24	0.25	0.10	0.10	0.10	0.20	0.36	0.15	(-	(-
" HYDROGEN IN COAL	(2.8	(3.42	4.28	4.31	4.20	4.20	3.60	4.30	4.29	3.81	2.30	2.34
" UNBURNED CARBON	2.5	2.24	1.80	2.20	0.70	0.70	1.40	1.50	6.20	1.98	4.20	3.35
" UNBURNED C. O.	-	2.22	0.40	0.44	0.20	1.00	0.40	0.60	0.00	0.00	0.30	0.00
" RADIATED & UNACCOUNTED	12.2	13.74	2.71	3.54	4.30	3.50	2.70	1.80	1.07	2.45	4.40	4.84

ITEMS	CAHOKIA STATION TESTS BY-A.KREISINGER 1924		LAKE SHORE STATION TESTS BY- JOHN WOLFF 1924		BROWN & SHARP TESTS BY-S.D.FITZSIMMONS 1925	I.R.T.59th ST. STA. TESTS BY- H. B. REYNOLDS 1926		CALUMET STATION TESTS COMMONWEALTH EDISON 1928	
TYPE	PULV. FUEL		PULV. FUEL		RILEY STOKER	TAYLOR STOKER		PULV. FUEL	
RATING PERCENT	130.4%	180%	152%	214%	120%	180%	232%	607%	862%
DATE OF TEST	April	May	May		Oct.5			Aug.30	Sept.5
NAME	No.4	No.6	No.15	No.9	One	No.5	No.8	No.8	No.9
HEATING SURFACE - SQ.FT.									
BOILER	18,010	18,010	30,600	30,600	3,000	11,400	11,400	5,940	5,940
WATER WALLS	-	-	-	-	-	-	-	2,468	2,468
SUPERHEATER	-	-	4,520	4,520	None	1,485	1,485	-	-
ECONOMIZER	None		22,080	22,080	None	None	None	8,828	8,828
AIR HEATER	None		None	None	None	None	None	41,703	41,703
E.B. PER $ BOILER S.	4,368	6,030	5,092	7,169	4,020	6,030	7,772	20.3	28.9
GRATE AREA						212	212		
TEMPERATURE - FEED WATER	194°	197°	137°	144°	195°	184.5°	187.1°	189°	187°
TEMP. GAS - FINAL EXIT	474°	502°	203°	259°	468°	475.5°	566.3°	221°	289°
PERCENT $C.O._2$ BOILER EX.	14.4	14.5	15.3	14.5	13.1	14.62	14.65	14.59	14.93
APPROXIMATE PERCENT EXCESS AIR	26.1	25.5	19.0	25.4	38.0	22.0	21.0	22.5	20.0
COAL - KIND	ILLINOIS		BITUMINOUS		W.VIRGINIA	BITUMINOUS		YOUGHIOUGHENY	
MOISTURE	7.08	5.63	2.30	1.70	2.41	2.93	3.43	2.23	2.43
CARBON			68.90	68.90	84.86	84.46	84.84	83.30	83.22
HYDROGEN			4.80	4.80	4.55	5.12	5.22	5.17	5.17
SULPHUR			3.70	3.70	0.91	1.54	1.39	2.42	2.52
NITROGEN			1.10	1.10	1.59	1.22	1.29	1.63	1.63
OXYGEN			8.10	8.10	2.91	0.82	0.59	7.48	7.46
ASH	11.40	11.38	10.50	12.60	5.28	6.84	6.67	12.53	12.80
B.T.U. PER LB. - DRY					14.871	14.588	14.716		
" " " AS FIRED	11.599	11.790	12.686	12.473	14.513	14.158	14.212	12.563	12.479
HEAT BALANCE - PERCENT									
ABSORBED BY BOILER & AC.	83.8	81.8	91.2	91.1	83.17	81.82	82.28	88.60	87.90
LOSS - DRY FLUE GAS	9.2	10.0	3.5	4.2	10.10	9.37	11.49	3.52	5.20
" MOISTURE IN COAL	-	-	-	-	0.21	0.25	0.31	0.20	0.22
" " " AIR	-	-	-	-	-	0.26	0.22	0.64	0.55
" HYDROGEN IN COAL	4.9	4.8	4.1	4.0	3.50	3.87	4.05	3.50	3.60
" UNBURNED CARBON	-	-	-	-	0.51	0.43	0.41	0.90	0.91
" UNBURNED C. O.	0.5	0.2	-	-	0.86	0.94	1.05	-	-
" RADIATED & UNACCOUNTED	1.6	3.2	1.2	0.7	1.65	3.06	0.19	2.64	1.62

cent was possible with pulverized coal, the improvement over Jacobus' tests being due to the fact that the carbon loss was 0.7 of 1 per cent, as compared with 1.8 per cent with the stoker. The successful operation of pulverized coal stimulated the redesign of the stoker to permit of operation at lower excess air and lower combustible loss.

There have been very few tests reported of underfeed stokers and boilers, without an economizer or

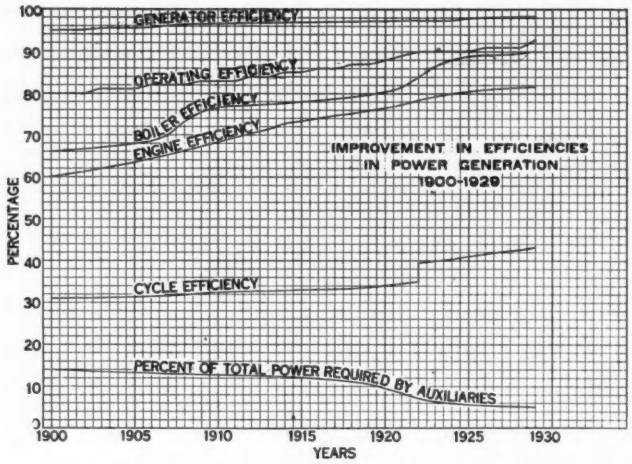


Fig. 4.—Improvement in efficiencies in power generation

air heater, but Reynolds in 1926, in his tests of the Interborough boilers, showed efficiencies as high as 82.28 per cent with a combustible loss of 0.41 and 21 per cent excess air, this high efficiency having been due not only to reduction in excess air and combustible loss, but also to a reduction in gas temperature, due to the fact that the boiler had twenty-four rows of tubes instead of the usual fourteen.

About this same period, engineers attacked the stack loss, by using air heaters, economizers, or both. In 1923, C. W. E. Clarke, reported an improvement of 7 points in efficiency due to the use of the air heater, and in 1925, John Wolf reported a combined efficiency of 91.2 per cent including the economizer. Details of these various tests are given in Table 1.

In 1901, the first steam turbine was installed in the plant of the Hartford Electric Light Company. At that time the ratio of actual to theoretical water rates (that is Rankine efficiency ratio) was about 58 per cent. Constant improvements in both the turbine and the electric generator has raised this ratio to about 80 per cent.

Even as late as 1915, when with underfeed stokers we could obtain combined efficiencies of boiler and furnace of 75 per cent. or better, we felt that we were good operators if the boiler efficiency for the month averaged 65 per cent; in other words, there was an operating efficiency of approximately 85 per cent. In many cases, the calculated fuel consumption was about 0.8 of the actual consumption. For a long time we laid this difference to banking losses, until calculations of such losses showed that something else was entering into the picture. We began to use higher grade boiler room labor and educated our men to combustion control. We installed CO_2 meters and watched the excess air and the carbon going to the ash pit. Slowly this operating ratio was improved until we find the designers of the State Line Generating Station figuring on an operating efficiency of 92 per cent, and 95 per cent is not impossible.

Before 1915, unless a plume of steam was floating from the auxiliary exhaust head, the plant looked as if it were shut down. At about that time we began to purchase new and more economical steam auxiliaries, substituting in many cases electric motors. Finally, around 1922, our auxiliaries became largely electrified. In 1900, probably 16 per cent of the total steam generated went to the auxiliaries; today 5 per cent represents the auxiliary power required at full load.

The efficiency of the cycle has naturally improved as steam pressures and temperatures have increased. Up until 1919, 28½ in. vacuum was considered to be the maximum commerical vacuum. We have passed that stage, and are talking of vacuums greater than 29 in. This has also increased the efficiency of the cycle. In about 1922 we began to use the regenerative cycle with an improvement in efficiency close to 5 points, and since that time, by increase in pressure and temperature, a further improvement of about 4 points has been secured.

The improvement in efficiencies is shown by Fig. 4. Using these figures as a basis, the total heat con-

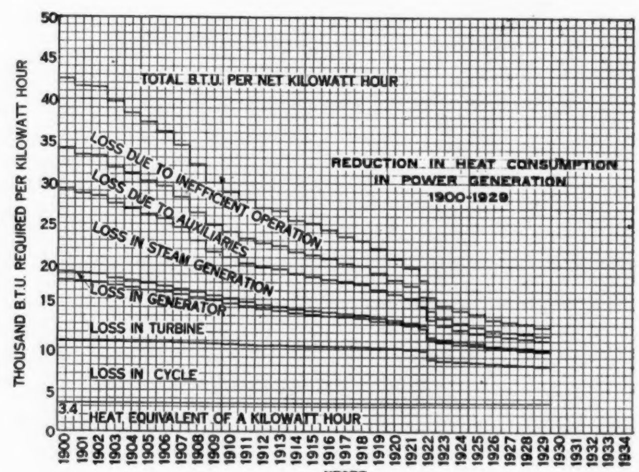


Fig. 5—Reduction in heat consumption in power generation

sumption per kw. hr. has been plotted in Fig. 5. There has not been much change in generator efficiencies, because there has been so little margin for improvement. Engine or turbine efficiencies have shown a marked improvement. The cyclic efficiency does not show so marked a change as one might expect, but the improvement in boiler efficiencies and operating efficiency is spectacular. From the chart it would appear that we haven't much farther

(*Continued on page 44*)

The Thermal Properties of Steam*

By WM. L. DE BAUFRE
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This article is particularly timely in view of the recent publication of new steam tables by the American Society of Mechanical Engineers. The evolution of values for the thermal properties of steam is an interesting story of persistent research dating back to the year 1769 when the earliest known experiments were made for the determination of the relation between temperature and pressure of saturated steam. Mr. De Baufre reviews the more important achievements which constitute the milestones of progress in the experimental determination of the properties of saturated and superheated steam, and concludes with a discussion of the thermal properties of wet steam.

IN combustion, steam generation, the production of mechanical power and other industrial processes, we are concerned with fluids and their thermal properties. Many fluids of widely different thermal properties are employed in such processes. Most of these fluids, however, are confined to certain industries so that the their thermal properties are of limited interest. Often this interest is further restricted to but few properties within narrow ranges of pressure and temperature. Water, atmospheric air and products of combustion, however, are almost universally encountered. Air and other gases will be discussed in a future article. The present article will describe how knowledge of the thermal properties of steam has grown with the conceptions of heat, of temperature and of the physical properties of fluids in general, and how more nearly exact values have become available for engineering calculations with improvements in experimental technique and with the adoption of more exacting specifications for the units of measurement, as explained in previous articles.

Early Experiments on Fluids

It was not until the middle of the 17th century that any real conception was acquired of the physical properties of fluids. Pascal wrote his treatise on equilibrium in liquids in 1653. Galileo discovered that air has weight, and the pressure of atmospheric air was measured by means of a mercury column by Torricelli in 1643. For two thousand years it had been said that nature abhors a vacuum; but it was then discovered that this abhorrence extends to about 30 inches of mercury only. Otto von Guericke constructed air pumps and experimented with exhausted globes. The mechanics of air were studied by Robert Boyle, who announced in 1662 the law known by his name.

About one hundred years later, Joseph Black discovered "latent heat" and found that the "capacity for heat" (specific heat) was different for different substances. Lavoisier in conjunction with Laplace, determined the specific heats of a number of substances about 1783. Gay Lussac's research on the expansion of gases with rise in temperature was published in 1802. The expansion of gases was also investigated by Dalton and by Dulong and Pettit in the early part of the 19th century.

The steam pumping engine had been developed during the early part of the 18th century with no quantitative knowledge of the thermal properties of steam. The earliest experiments on the relation between temperature and pressure of saturated steam appear to have been made in 1769 by Ziegler, a Swiss. Similar experiments were later made by Betancourt, a Spanish physicist, and published in 1790. The Encyclopedia Britannica for 1797 contains under the article "Steam" furnished by Dr. Robison, a table of the elastic force of aqueous vapor for every 10 degrees from 32 to 280 fahr. Robison, as well as the previous investigators, assumed the pressure of steam to be zero at the temperature of melting ice. This misconception was corrected by Dalton, who published his researches on steam in 1802. His observations extended from 32 to 212 fahr. and were extrapolated by him to minus 40 fahr. and to 325 fahr.

Black measured the latent heat of ice by the temperature of one pound of water which, when mixed with one pound of ice, would melt the ice without causing its temperature to rise above 32 fahr. He attempted to measure the latent heat of steam by comparing the time of raising the temperature of water a certain number of degrees with the time of boiling it off by the application of the same external heating. Watt in 1781 determined the latent heat of steam under atmospheric pressure to be about 950 "degrees" by measuring the rise in temperature of a pan of water in which the steam was condensed. Watt also found that water would distill in vacuo when at the temperature of 70 fahr. and that in this case the latent heat appeared to be about 1000 "degrees." From these and other unpublished experiments, he concluded that the sum of the sensible and latent heats of steam was a constant quantity. This statement was known for

many years as Watt's law although disputed by Southern who made experiments at pressures of 40, 80 and 120 in. of mercury above atmospheric pressure and concluded that the latent heat was a constant quantity. It will be noted that Watt expressed the latent heat of steam in "degrees" because a heat unit had not yet been adopted.

Watt also measured the specific volume of steam. He put a small amount of water into a glass flask which he weighed and placed in a fire until all the water evaporated. He then removed the flask from the fire, cooled and weighed it. He also weighed the flask dry and full of water. From these data, he calculated that steam occupies a volume 1800 times that of water.

Gay Lussac's method of determining the densities of vapors consisted in finding the volume occupied by a known weight of liquid after being converted into vapor at a certain pressure and temperature. A small bubble of thin glass containing a known weight of liquid was introduced into an inverted jar containing mercury. The mercury was then heated, the glass bubble bursting by expansion of the fluid it contained. The mercury was immediately depressed by the pressure of the vapor formed. If the measured vapor pressure was less than the maximum value at the same temperature as found by employing larger quantities of liquid, it was certain that all the liquid had been converted into vapor. By means of Boyle's law, the density was calculated at the maximum pressure corresponding to the temperature of the experiment. From experiments with water vapor and one or two other vapors, it was concluded that Boyle's law applied to vapors near the point of condensation as well as to "permanent gases."

The continued development of the steam engine during the first half of the 19th century with the employment of steam pressures appreciably above atmospheric pressure, called for more extensive and reliable data on the thermal properties of steam. The results of Ure's experiments on the vapor pressures of water and several other substances were published in 1818. Despretz's experiments appeared in 1819. The French Government in 1823 appointed a scientific commission to secure data upon which to base legislation regulating the working of steam engines and boilers. This commission, consisting of Prony, Arago, Girard and Dulong, experimentally determined the pressure of saturated steam up to a temperature of 224 centigrade, at which temperature the corresponding pressure is about 27 atmospheres. The pressure was measured by applying Boyle's law to the compression of air in a closed tube over mercury. From preliminary experiments, they concluded that Boyle's law was strictly true for air up to a pressure of 27 atmospheres and probably to a considerably higher limit. About 1836, a committee of the Franklin Institute was appointed at the instance of the United States Government to inquire into the causes of steam boiler explosions; and in the course of their inquiries, this committee instituted experiments on the pressure and temperature of saturated steam.

The Experiments of Regnault

The experimental determinations of the thermal properties of steam, air and certain other fluids made by Regnault at the expense of the French Government and under the direction of the French Academy of Sciences, published in 1847, 1862 and 1870, constituted the standard thermal data on these substances for half a century. Even today, some of his data may be used by reason of the care employed in the experimental procedure and the consequent accuracy of the results obtained. By greater accuracy than had previously been used in such measurements, Regnault proved that no gas obeys Boyle's law exactly and that all gases do not have quite the same coefficient of expansion as stated by the law of Gay Lussac.

His memoir on the elastic force of aqueous vapor gave the pressure and corresponding temperature up to about 28 atmospheres corresponding to 230 centigrade. He gave a formula for the pressure-temperature relation which will not be included in this article. Regnault measured the total heat of steam by condensing it in cold water under an artificial atmosphere equal in pressure to that of the steam condensed. He found that the total heat of steam is not constant as claimed by Watt, but might be represented between 0 and 200 centigrade by the formula

$$H = 606.5 + 0.305\ t$$

where H is in calories per gram and t is in degrees centigrade above zero centigrade. Regnault also investigated the specific heat of water by discharging from a boiler under various pressures corresponding to temperatures between 107 and 187 centigrade, small quantities of water into larger quantities of water at atmospheric temperature and pressure. From these experiments, he derived for the total heat of water in calories per gram the formula

$$h = t + 0.000{,}02\ t^2 + 0.000{,}0003\ t^3$$

Regnault made four experiments on the specific heat of superheated steam, all at atmospheric pressure, by injecting into water at room temperature, a known weight of steam, first slightly superheated and then highly superheated. All experiments were made for about the same temperature range of the superheated steam, namely, from 125 to 225 centigrade. As a mean of the four experiments, he calculated the specific heat of superheated steam to be

$$c_p = 0.4805$$

These classical experiments of Regnault formed the basis for all tables of the thermal properties of steam prepared up to the beginning of the 20th century. None of the tables extended into the superheated region. The densities of dry saturated steam were either calculated from Regnault's data by means of thermodynamic relations that exist between cor-

responding values of temperature, pressure and latent heat, or the densities were derived from experiments made in 1860 by Fairbairn and Tate upon the volumes of steam in the pressure range of 3 to 60 lb. per sq. in. absolute. There were discrepancies in the densities obtained by the two methods amounting to as much as 3 per cent. These steam tables, however, were considered sufficiently accurate for all practical purposes as late as 1890. At that time, the steam consumption of reciprocating engines greatly exceeded the piston displacement so that accurate volumetric calculations were unnecessary, and superheated steam was rarely encountered except in the throttling calorimeter where Regnault's single value of its specific heat at atmospheric pressure was sufficient for the calculations involved. Regnault's value of 0.48 for the specific heat was erroneously applied to superheated steam at any pressure and temperature when occasion required the total heat of superheated steam above atmospheric pressure.

The Critical Temperature

Even before Regnault's experiments, new conceptions were being developed on the gaseous and liquid states of matter. The first important work on the liquefaction of gases was performed by Faraday. His experiments, beginning in 1823, showed that most gases could be liquefied. Notwithstanding the experiments of Thilorier in 1835, of Natterer in 1845 and Faraday's later work in 1845, several gases resisted liquefaction and were classed as "permanent gases" until 1877.

As early as 1822, Latour observed that ether, alcohol and water, when heated in sealed tubes, were apparently totally changed into vapor occupying only two to four times the original volume of the liquid. But the discovery of the continuity of the liquid and gaseous states belongs to Thomas Andrews who wrote in 1863 that upon gradually raising the temperature of partly liquefied carbon dioxide to 88 fahr., the surface of demarcation between the liquid and gas became fainter, lost its curvature and at last disappeared. Above 88 fahr., no apparent liquefaction of carbon dioxide could be effected even when a pressure of 300 or 400 atmospheres was applied. This temperature was called the "critical point" by Andrews, who in 1869 expressed the opinion that failure to liquefy the "permanent gases" was due to their critical temperatures being lower that the lowest temperatures hitherto applied to them. Taking this hint, Pictet and Cailletet demonstrated in 1877 that the "permanent gases" can be liquefied by a sufficient reduction in temperature. Oxygen was first liquefied, followed quickly by the liquefaction of nitrogen and atmospheric air and later by hydrogen. The critical temperatures of these substances are: Oxygen, -182 fahr.; air, about-221 fahr.; nitrogen,-233 fahr.; hydrogen,-400 fahr. Steam has a critical temperature of 706 fahr. with a corresponding critical pressure of 3226 lb. per sq. in. absolute. A steam generator to operate above the critical temperature and pressure must be designed along entirely different lines than the ordinary steam boiler because under such conditions there is no distinct line of separation between water and steam by which to regulate the rate of feed of water to the generator.

Improved Steam Tables

The growth of public utility and industrial power plants towards the end of the 19th century called for greater economy in the consumption of fuel to furnish the heat for generating the mechanical power required. This resulted in the use of higher steam pressures and of lower exhaust pressures and the employment of superheated steam in order to increase the thermal efficiency of the prime movers. The development at the same time of the steam turbine necessitated greater accuracy in thermodynamic calculations based on the thermal properties of steam than had hitherto been required with the reciprocating steam engine. The older tables of the thermal properties of steam did not fulfill the requirements because the were neither accurate nor thermodynamically consistent.

There became available near the end of the 19th century and in the first few years of the 20th century, experimental data which enabled steam tables to be prepared covering the superheated region and having greater accuracy than those based on the work of Regnault. Rowland found during his experiments in 1879 on the mechanical equivalent of heat that the specific heat of water decreased between 5 and 35 centigrade rather than increased continuously with the temperature from the melting point of ice as was assumed by Regnault. This decrease was confirmed by the experimental data on the specific heat of water published by Ludin in 1895, by Barnes in 1902 and by Dieterici in 1905. Since Regnault's time, many ivestigations had also been made on the temperature-pressure relation of saturated steam, the best data undoubtedly being those obtained at the Reichsanstalt in Germany by Holborn and Henning in 1908. New data on the total heat of steam became available through the experiments of Dieterici in 1889, of Griffiths in 1895, of Henning and of Joly in 1906 and of Smith in 1907. The specific heat of superheated steam had been measured by Knoblauch and Jakob in 1906 and by Thomas in 1907 at pressures above atmospheric pressure and for various temperature ranges; also, Holborn and Henning had extended their measurements of the specific heat at atmospheric pressure to 2450 fahr. The specific volume of superheated steam had been measured by Ramsay and Young in 1892, by Batelli in 1894 and by Knoblauch, Linde and Klebe in 1905. Observations on the critical pressure and temperature had been made by Nadejdine in 1885, by Batelli in 1890 and by Dieterici in 1904. These data were used in the preparation of steam tables by Marks and

Davis published in 1909, being the first American tables to cover the superheated region. No attempt was made to have the tabulated values entirely consistent thermodynamically, the various values being based on what was considered the most reliable experimental data.

A steam table is thermodynamically consistent when the tabular values are obtained from equations that are properly connected by thermodynamic relations. The discovery of the continuity of the liquid and gaseous states brought forth efforts to find an "equation of state" which would represent the relation between the pressure P, the volume V and the temperature T of a fluid in the liquid as well as in the gaseous state. The expression for the combination of the laws of Boyle and of Gay Lussac, namely,

$$P V = R T$$

was accordingly modified with this object in view. The molecular theory of gases shows that a gas cannot exactly conform to the above equation unless the size of the molecules is infinitesimally small and there is no mutual attraction between the molecules. In order to take account of these two effects, Van der Waals in 1873 proposed for actual fluids, the equation of state

$$(P+a/V^2)(V-b) = R T$$

where b represents the deduction from the total volume V due to the volume of the molecules and a/V^2 is added to the pressure P to represent the attraction between the molecules. In attempting to apply this formula to actual fluids, a and b are found to be functions of the temperature T or the specific volume V or both rather than constants.

For steam, Callendar proposed in 1900 an equation of state of the form

$$(v-b) = R T / p - c / T^n$$

This equation was used by Mollier in the preparation of steam tables published in 1906. Callendar used it for steam tables published in 1915. Goodenough's tables, also published in 1915, were based upon a similar formula, namely,

$$(v-b) = B T / p - (1 + 3 a p^{1/2}) m / T^n$$

Heck and others have proposed various modifications in the equation of state for steam.

In addition to an equation of state, it is necessary to adopt some mathematical expression for the relation between the pressure p and the temperature T of saturated steam, such as

$$\log p = A + B/T + C \log T + DT + ET^2 + \text{etc.}$$

Then, by aid of Clapeyron's relation

$$L = (v_g - v_f) A T \, dp/dT$$

between the pressure p, the temperature T, the latent heat L, the specific volume v_g of saturated steam and the specific volume v_f of water at the same pressure and temperature, and by certain other thermodynamic relations based on the work of Clausius, a consistent set of formulas may be obtained for calculating all thermal quantities. Goodenough's tables were the most nearly accurate of the thermodynamically consistent tables prepared previous to the A. S. M. E. research on the properties of steam.

The A. S. M. E. Steam Research

On June 23, 1921, a group of scientists and engineers met in Cambridge, Mass., and discussed the available information on the properties of steam. As a result, a research program was planned to obtain more data and the American Society of Mechanical Engineers was requested to sponsor the program and raise funds therefor. This request was granted and the research program has so far progressed that Steam Tables by J. H. Keenan have just been issued by the Society.

Up to the time of this meeting, nearly all experimental work on the properties of steam had been carried on below 250 lb. pressure and the data so obtained extrapolated by compilers of steam tables to the higher pressures which were coming into commercial use. Turbine designers found differences in their design calculations when different steam tables were used. Thus, in calculating the heat drop from an initial pressure of 500 lb. and a temperature of 725 fahr. to a final pressure of 150 lb., a difference was found as high as 4.6 per cent. For the initial volume of the steam, a difference of 6 per cent was found.

It was originally planned to have the Joule-Thomsen cooling effect in superheated steam investigated up to 600 lb. and 600 fahr. at the Harvard Engineering School, to have the pressure-temperature-volume relation of superheated steam investigated at high pressures at the Massachusetts Institute of Technology, and to have the U. S. Bureau of Standards measure the specific heat of water between the freezing and boiling points in order to determine more accurately the mechanical equivalent of the mean heat unit. The work at the U. S. Bureau of Standards has since been extended to cover the heat content of water above the boiling point and calorimetric measurements have been made of the latent and the total heat of steam.

The data obtained in these various investigations have been found consistent among themselves and with certain other data which have become available from other sources, notably that on the specific heat of superheated steam and the latent heat of saturated steam from the Reichanstalt in Germany. No simple formula of the Callander-Goodenough-Heck type, however, has been found to represent the pressure-volume relation of steam. Although certain formulations have been used for interpolation of the experimental data in the superheated region, the thermodynamic consistency of the steam tables prepared by J. H. Keenan and published by the American Society of Mechanical Engineers depends in the main on the accuracy of the experimental data.

International Steam Table Conference

During July, 1929, there was held in London a conference of the various physicists and engineers

who were connected with research work on the properties of steam in Great Britain, Germany, Czechoslovakia and the United States. After discussing the work which had been in progress by the various investigators, it was agreed to draw up in skeleton form a small table of the properties of steam with tolerances which would indicate the uncertainty of the mean values selected from available experimental data. For saturated steam, there was accordingly drawn up a table giving the saturation pressure, the specific volume of liquid, the specific volume of vapor, the total heat of liquid and the total heat of vapor corresponding to the temperatures of 0, 50, 100, 150, 200, 250, 300 and 350 centigrade. For superheated steam, tables were prepared of the specific volume and of the total heat for a number of pressures from one to 250 atmospheres and for temperatures in steps of 50 degrees up to 550 centigrade. It was agreed that any steam table in which the tabulated values were within the tolerances given should be considered an International Table. Keenan's Steam Tables were prepared before this international conference; but as the values come within the allowed tolerances, they meet the requirements of an International Table.

Thermal Properties of Wet Steam

The temperature-entropy diagram of Fig. 1 has been plotted from the values given in Keenan's Steam Tables, in order to indicate the differences between wet and dry steam and between superheated and saturated steam. In the application of heat to water in a vessel, the temperature of the water rises until it reaches a definite value corresponding to its pressure and then the water begins to boil without further rise in temperature. If, for example, the pressure is 100 lb. per sq. in. absolute, the temperature of boiling will be 327.83 fahr. according to Keenan's Tables. Water at this saturation temperature is represented by point A on the "saturated liquid line" in Fig. 1. If boiling takes place without change in pressure, the temperature will remain constant as indicated by the dotted line AB. At any instant, there will be a mixture of saturated steam and saturated water in the vessel, that is, the vessel will contain "wet steam." The point B on the "saturated vapor line" corresponds to the evaporation of the last particle of water and therefore to dry steam. The steam, however, is still saturated; that is, the steam has its maximum density rather than a lower density which would result from further heating above its saturation temperature. If superheated at constant pressure, the temperature will rise as indicated by the dotted line BC.

Thus, steam which has the maximum density and the minimum temperature corresponding to its pressure, is saturated steam. Dry saturated steam contains no liquid dispersed through it. If it contains dispersed liquid, the steam is wet and saturated. Superheated steam has a lower density and a higher temperature than saturated steam under the same pressure. Superheated steam is dry. Superheated steam is occasionally found in contact with water due to its low heat conductivity; also, steam may at times be cooled to a temperature lower than that of saturated steam under the same pressure and is then known as supersaturated steam; but these are unstable conditions that exist only temporarily.

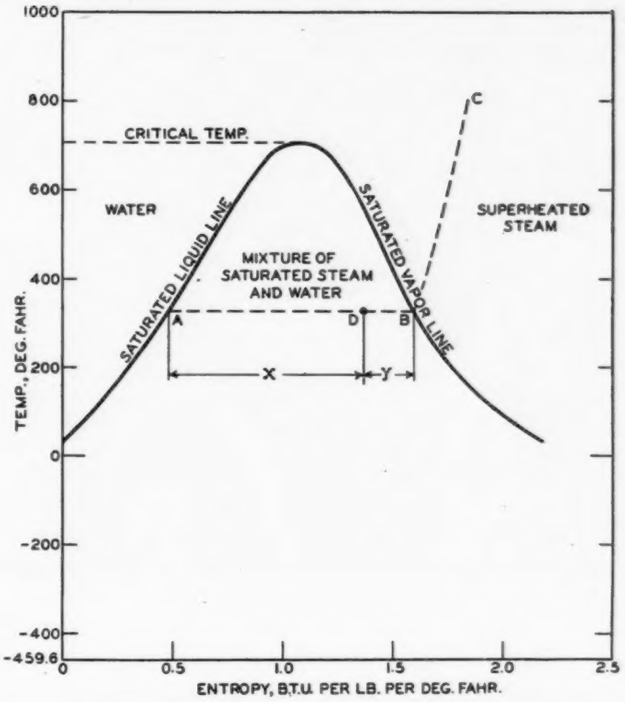


Fig. 1—Temperature-entropy diagram for steam

In Fig. 1, the region to the right of the "saturated vapor line" and above the "critical temperature", represents superheated steam, the gaseous state of water. The region to the left of the "saturated liquid line" and below the "critical temperature", represents the liquid state of water. The region below the "saturated liquid line" and the "saturated vapor line", which meet at the critical temperature, represents a mixture of the liquid and gaseous states, or wet steam. The point D, for example, represents a mixture of liquid corresponding to point A and of vapor corresponding to point B, both at the same temperature.

The quality of wet steam is stated in terms of its "dryness fraction" or the "percentage of moisture" contained therein. If x and y denote the dryness and moisture fractions respectively, then $x + y = 1$. The latent heat added to one pound of water to produce wet steam of quality x, is given by $x\ h_{fg}$, or $(1-y)\ h_{fg}$, where h_{fg} is the latent heat per pound of dry steam. The total heat of wet steam is equal to the heat of the liquid h_f plus the latent heat, or

$$h_f + xh_{fg} = h_f + h_{fg} - yh_{fg} = h_g - yh_{fg},$$

where h_g is the total heat of dry saturated steam.

(*Continued on page 57*)

Recovering Unburnt Fuel from Ash Pit Refuse

By DAVID BROWNLIE, London

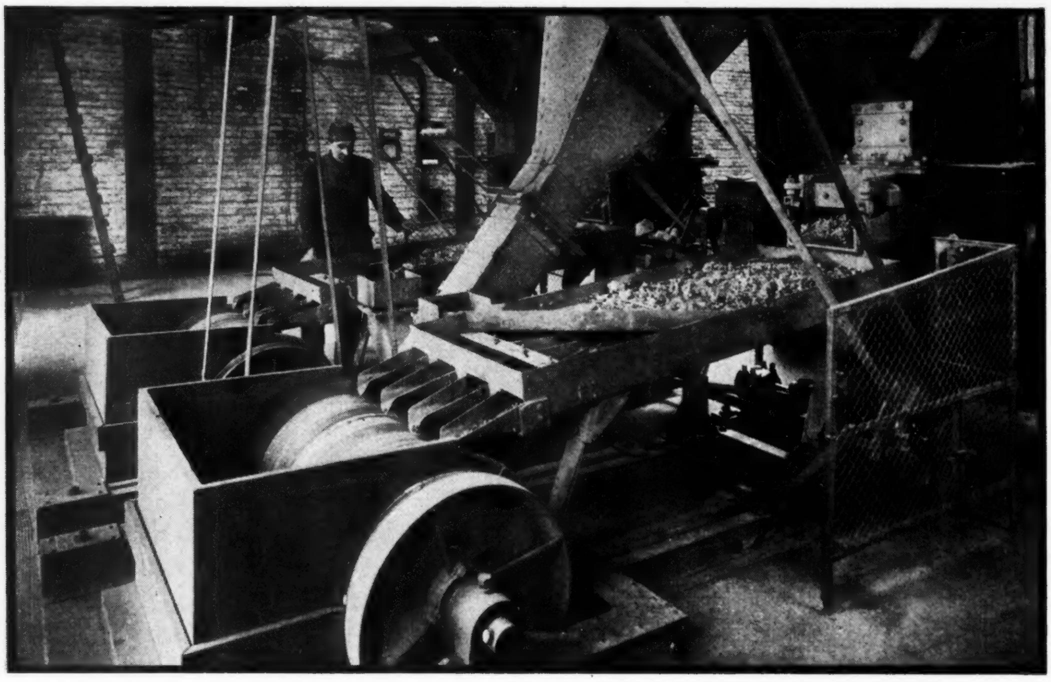


Fig. 1—Krupp-Grusonwerk ash and clinker treatment plant at the Stettin Power Station, Germany

The recovery of unburnt fuel from ash pit refuse has been practiced to quite a considerable extent in Great Britain and in certain European countries. In England, this practice seems to have found particular application in connection with gas plant operation. The author describes two of the most extensively used processes and presents interesting data relative to the economic aspects of typical gas plant and steam plant installations.

UNTIL quite a few years ago it was the general opinion that ash pit refuse, or what is commonly termed "ash and clinker," from boiler plants and coal fired furnaces of almost every description, as well as total gasification generators, contained either no unburnt coal or coke at all, or an amount purely negligible, such as less than 5 per cent by weight of the ash and clinker or say 0.5 per cent by weight of the original coal. It is true, of course, that with the latest methods of pulverized fuel firing, and to a lesser extent with mechanical stoking, such results are secured under the most scientific conditions of control and operation. However, the idea, still too generally held, that the losses due to unburnt fuel in ash pit refuse, incident to the consumption of about 600,000,000 tons of coal per annum in steam boilers, are trifling, certainly belongs to what may be termed the pre-scientific age of steam generation. Anyone with real experience in boiler plant or producer gas generator work knows that the combustible material, both unburnt coal and coke, in ash and clinker may be very considerable in amount.

In my own experience I once came across a case, incredible though it may sound, in which a small power station with chain grate stokers was selling the ash and clinker for a trifling sum to a neighboring factory for the supposed purpose of making roads in the works. In reality, however, the enterprizing purchaser used it as fuel in hand fired Lancashire boilers and obtained an average evaporation of about 4.0 lb. of water per lb. of ash and clinker.

In quite a lot of cases from 40 to 50 per cent of unburnt fuel is present in ash and clinker and in this connection I do not agree with the general idea that, on the average, hand fired plants are inferior in this respect to those equipped with mechanical stokers. The worst offenders are often the ordinary chain grates and various other types of mechanical stokers, for Lancashire and other internally fired cylindrical boilers, that are not sufficiently flexible to avoid the necessity of slicing the fires by hand when the steam demand is high.

Taking an average through all kinds of plants, probably about 20 to 25 per cent of unburnt material,

mostly coke, is present in ash and clinker from boiler furnaces and from 35 to 40 per cent from total gasification generators, especially as used in gas works. Thus with 600,000,000 tons of coal burnt per annum in the world under stationary boilers, having say 15 per cent ash, that is 90,000,000 tons, the loss due to unburnt material is equivalent to about 20,000,000 tons of coal per annum. In the case of a power station consuming 1,000 tons of coal per day, producing say 150 tons of ash and clinker in this time, it would be interesting to know the exact loss of unburnt material even in a most modern installation. While the loss in such an instance would unquestionably be of considerable proportions, it would be very much greater per ton of fuel in connection with gas works, the iron and steel, glass, and ceramic industries, and railroad locomotives. Certainly it would seem to be a paying proposition in many cases to install a separating plant to treat all the ash and clinker and recover the unburnt coke and coal. As against this however, as with many other branches of the treatment of refuse material, the real net saving is apt to be much less than expected after deducting the capital cost, maintenance, labor and power charges. It, therefore, becomes necessary to consider each individual case on its merits.

Unburnt fuel can, of course, be recovered from ash and clinker, in many cases with reasonably satisfactory results, by crushing and then treating in one of the many types of ordinary coal cleaning plants, or even by hand-picking on long travelling picking belts or tables.

This article, however, will confine itself to a description of two representative European machines, both of German manufacture, and specially designed, but on quite different principles, to treat ash and clinker continuously in large quantities. The first of these is the "Columbus" which is a gravity separator, using a liquid, the ash and clinker being heavier, and therefore sinking, while the lighter coal and coke float; the second is the "Ulrich," a machine provided with magnets which attract the ash and clinker but not the fuel. There are other separators on the market, but these are regarded as two of the most important, and are also representative of the wet gravity and the dry magnetic methods.

The "Columbus" is manufactured in Great Britain by Aldridge and Ranken of London and uses water to which clay is generally added to make a liquid of from 1.20 to 1.25 sp. gr. The essentials of the design are illustrated in Fig. 2. It consists of a horizontal revolving sieve drum (B), into which the ash and clinker are fed through the opening (A), the fine dust which interferes with the gravity separation being thereby screened out. From this screen the material goes through a very large mesh grid (C) to retain large lumps of slag which have no calorific value, these being discharged as waste by a chute (E). The main bulk of the material, now free from both dust and lumps, falls down the chute (D) into the main separator chamber (F), which is of inclined cylindrical pattern and is provided with two superimposed worm conveyors (G) and (H), operating in separate chambers.

The lower portion of this separator cylinder contains water to the level indicated which is raised in specific gravity as mentioned by adding any cheap mineral such as clay, chalk, carbide lime waste, or spent brine, so as to give a more effective

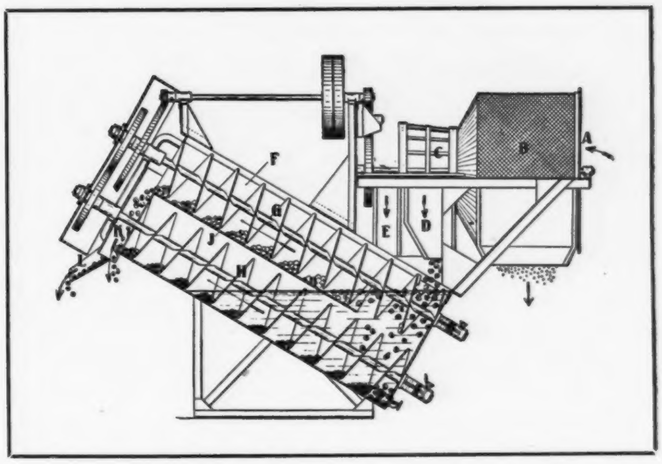


Fig. 2—Cross section of the Columbus gravity type separator

separation than is possible with water alone. The graded material, continually falling into this water, immediately separates by gravity, the ash and clinker falling to the bottom and the coal and coke floating on the top. Consequently the upper worm conveyor (G) picks up the coal and coke and discharges it from the upper end of the cylinder by a chute (K), while the lower worm (H) takes the ash and clinker from the bottom of the liquid and passes it out by a separate chute (L). The two worms (G) and (H) and the revolving screens, together with any conveyor used to bring the material to the screen, are driven by one driving shaft. It is claimed that the coal and coke are only wetted to a superficial degree.

The general arrangement of a complete Columbus plant is illustrated in Fig. 3, the upper part of which shows a typical large installation with an inclined, endless chain conveyor for the ash and clinker, long rotary screen separator, and various discharge chutes to trucks for the medium sized ash and clinker (a), the coal and coke (b), the large lumps of clinker (c), a portion containing a considerable amount of granular coke (d), and the fine dust (e). The drawing in the lower part of the illustration shows a much smaller plant supplied by hand trucks with a very short endless chain conveyor, the coke recovered being 1/4 in. in size and upwards.

Columbus separation plants are made in several standard types and sizes for capacities of from 2 cu.

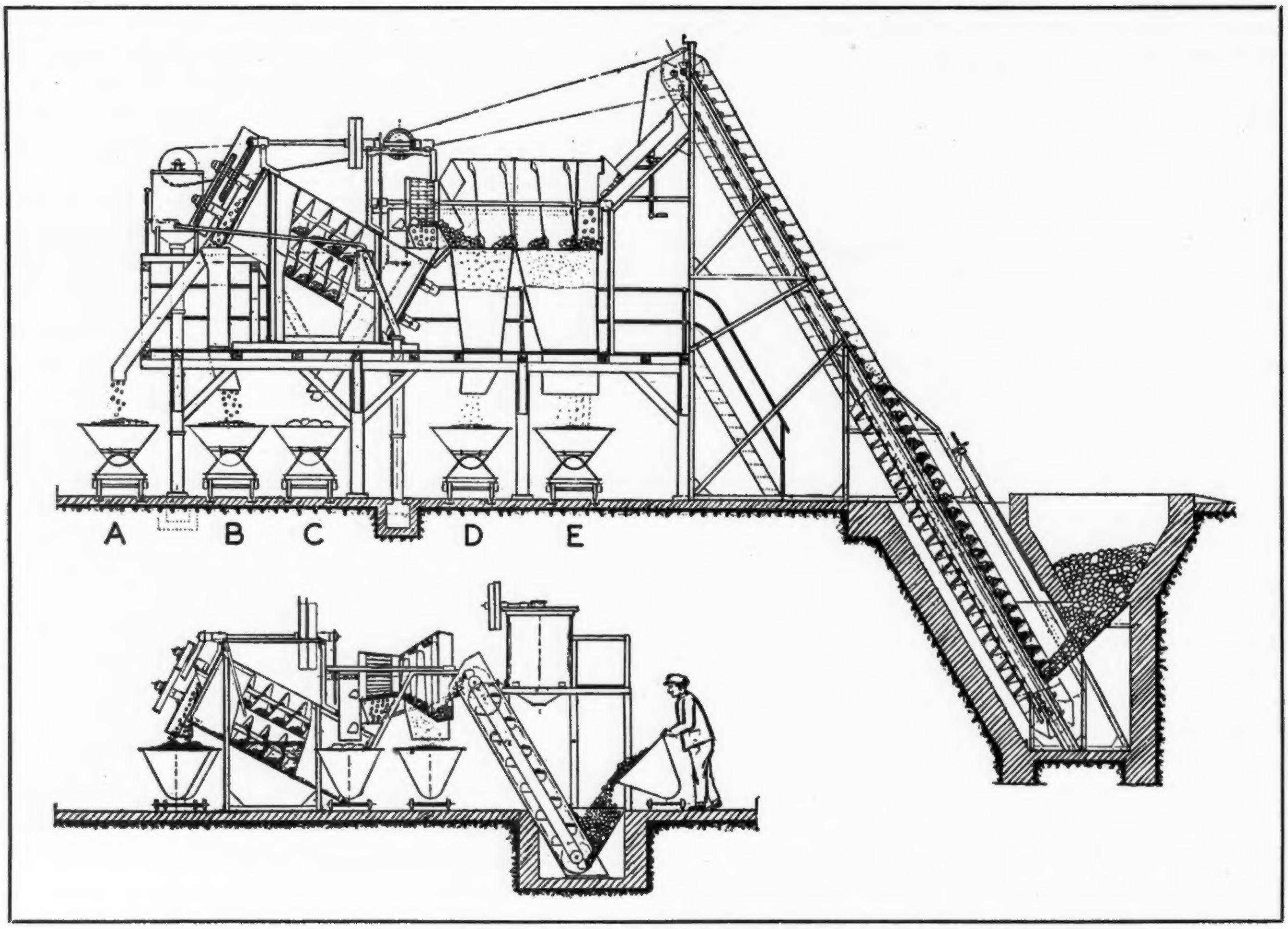


Fig. 3—Typical layouts of the Columbus gravity separation plant. The upper view shows a relatively large plant, and the lower view a small installation

yd. per hr., requiring 2½ to 3 hp. for drive, to 16 to 20 cu. yd. per hr., requiring 10 to 12 hp. A portable unit is also made which is entirely self contained and driven by a gasoline engine.

The separated fuel has a slightly muddy appearance because of a very fine film of clay, which makes no practical difference in its heating value nor in its adaptability to use. If, however, it is desired to sell the material to outside consumers a special rotary washer and grader can be added which removes this film with the use of a small amount of water and restores the fuel to its original color.

In Great Britain the Columbus separator finds its main application in municipal gas works, recovering coke from the ash and clinker of the retort generator plant. In one very large gas works in England the total amount of ash and clinker is 1,172 tons per 24 hours, composed of 27.8 per cent coke, 48.9 per cent clinker and 25.3 per cent dust. This is treated with Columbus machines and the gross value of the coke recovered is $3.60 per ton of ash and clinker. The net operating costs are $0.80 per ton so that the profit is $2.80 per ton, although the value of coke in this area is higher than usual. Typical water gas refuse in English practice analyzes about 25 per cent coke, 13 per cent coke breeze, 33 per cent clinker and 29 per cent fines. For the most part, the profit per ton of refuse handled would seem to be from $1.40 to $1.90.

The Ulrich magnetic separator is a production of The Fried. Krupp-Grusonwerk A. G., of Magdeburg-Buckau. This firm makes a specialty of electromagnetic separating plants for all kinds of operations, among the most important of which is the recovery of coal and coke from ash pit refuse. Other operations in which these separators are used are the removal of tramp iron from coal, separation of iron from metal scrap containing other metals such as brass, bronze, aluminum, and white metal, and from scrap generally, and the grading of ores or mixtures of ores, according to their magnetic properties.

With regard to the removal of fuel from ash pit refuse, the basic principle is that the original oxide of iron in the raw coal, which is not magnetic, is changed by the action of the furnace into magnetic oxide of iron as a result of which the ash and clinker, because of this iron content, are more or less subject to magnetic attraction whereas coal and coke are not affected.

Krupp-Grusonwerk have had the most extensive experience in this field, both as regards research work and the actual running of a very large number

of plants in Germany and elsewhere operating on every description of ash and clinker from boiler furnaces as well as many other types of furnaces. They state that the results of over 2,000 tests indicate that all ash and clinker from coal are magnetic, and that the same principle applies to ash and clinker from lignite.

The Krupp-Grusonwerk plant consists essentially of a feed hopper for the ash and clinker, which is crushed if necessary, a shaking screen, and a rotary drum containing as many magnets as may be required.

The function of the shaking screen, which is short in length, is to give a uniform continuous feed of the material throughout the full width of the drum. As a result, the ash and clinker, as they are carried around, adhere to the magnetized drum whereas the coal and coke slide off immediately. On completing a half-revolution the refuse material comes under the influence of other more powerful stationary magnets and is pulled off. When that portion of the drum thus cleared has revolved to a point when it is again in proximity to the shaking table, it picks up another load and the process is repeated.

For smaller plants having a capacity of from 1/4 to 3 tons of ash and clinker per hour, one feed hopper, one shaking tray, and a single rotary magnetic drum is sufficient, while for larger installations 2 to 4 shaking tables or more are used, placed side by side, with a drum of the necessary width and a corresponding number of magnetic fields, as well as a wide composite hopper. In almost all cases it has been found desirable to screen the ash and clinker into two or more sizes and use a separate shaking table and portion of the drum for each size.

A typical Krupp-Grusonwerk complete plant, with certain modifications to suit the local requirements, consists of a combined unit comprising a picking belt to separate large pieces of coal by hand, an inclined bucket elevator and quadruple shaking screen with drums having say four magnetic fields. A plant of this character is available in a portable type, Fig. 4, which can be taken easily from one spot to another and used for any local pile of ash

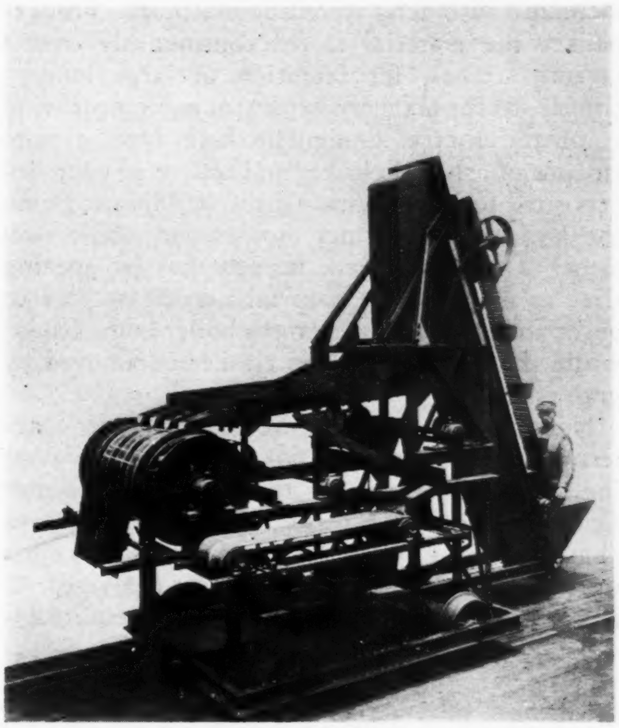


Fig. 4—Krupp-Grusonwerk separator of the portable or traveling type

and clinker. This type is used in many cases where there is not sufficient refuse at any one point to keep a stationary plant busy.

As regards the results obtained, interesting data are available pertaining to a Krupp-Grusonwerk installation which has been in continuous operation for several years at the Stettin Power Station in Germany. This installation operates in direct connection with the ash removal plant in the boiler

Fig. 5—Columbus installation at a well known London gas plant. This installation has a capacity of 2 cu. yd. per hr.

house, the latter consisting of two independently driven lines of shaking troughs, either of which will take all the ash and clinker from the boilers, discharging to a crusher hopper. Here the material is crushed down to about 1½ in. size and then taken by conveyors to an overhead bunker, the circuit including automatic weighing machines. From this bunker the material is fed continuously over vibrating screens, for retention of large lumps of clinker, to the magnetic separator equipment, which is of the rotary 4-magnetic field type, the two streams of ash and clinker and recovered coke being deposited separately outside the building, adjoining the boiler house, which houses the whole equipment. The arrangement is such that by opening a slide at intervals the coke falls down on to a conveyor and is taken direct to the boiler house bunkers, while the heap of ash and clinker is removed by a grab crane.

Normally this plant at the Stettin Power Station recovers about 8 tons of coke per 24 hours averaging about 8640 B.t.u. per lb. Detailed performance figures, taken over a period of 5 months, are available. During this time 4,872 tons of ash and clinker were treated and 1,218 tons of coke recovered, that is 25 per cent by weight. The power required was

Fig. 6—Another view of the Krupp-Grusonwerk installation at the Stettin Power Station, Germany

4.91 kw-hr. per ton of ash and clinker and the total cost during the 5 months was $1,122.27. The analysis of this cost is as follows: power—$299.15, labor—$336.00 (only one man per shift), and other expenses, including maintenance, material, and incidentals $487.12. The total operating cost was, therefore, approximately $0.23 per ton of refuse handled.

The coal used at Stettin has a heating value of from 10,800 to 11,700 B.t.u. per lb., and the price delivered is $5.88 per ton. Taking the coke as worth 70 per cent of the coal, weight for weight, which is conservative as indicated by the relative heating values, the recovered fuel has a value of $4.11 per ton and the total fuel recovered in 5 months has a value of $5,005.98, representing a profit of $3.19 per ton of recovered fuel, or a total profit, for the period, of $3,883.71.

For 12 months' operation, therefore, the profit on the plant, exclusive of fixed charges, is $9,318.48, and the cost of recovering each ton of fuel is $0.93. No quenching of the ash is required, the hot material being taken direct to the separation plant. It is also claimed that there is a saving in labor as compared with ordinary methods of ash handling.

In concluding, the author wishes to express his appreciation to Aldridge and Ranken, the Fried. Krupp-Grusonwerk A. G., and J. Rolland and Co., for their cooperation in providing data and illustrations.

Economies in the Generation and Distribution of Power

(Continued from page 34)

to go, but we start the year 1930 as a base with 100 per cent, and our improvements from now on will become percentages of 1930. Those percentages will look small when compared with 1900, but will be large in point of dollars in the years to come. What the future will bring to us is an idle speculation. The writer feels confident that 450 lb. or thereabouts and 725 deg. will be the usual condition for a number of years to come. In the high load factor large capacity generating station, we shall expect to see about 1400 lb. and possibly 900 deg., and in a few plants, frankly experimental, we may expect still higher pressures.

The lesson, if any, to be derived from this analysis is in the value of small economies. We can leave to the turbine designer the problem of improving turbine efficiencies, and to the boiler manufacturer the problem of building boilers for higher pressures to operate with commercially clean water, but the operating engineer still has the possibility of upsetting designer's forecasts by careless operation.

We should begin to rate our plants on the basis of their operating efficiency, that being the only efficiency over which the operator has any control. The management can help him by interconnections, which will improve the load factor but the operator can raise his own efficiency by watching mainly two items—excess air and combustible in the ash pit, and by watching those minor losses which frequently escape attention.

Development of a High Pressure System for Boiler Water Conditioning*

Discussion by R. E. HALL
Hall Laboratories, Inc., Pittsburgh.

***The subject paper by A. A. Markson was presented before the Metropolitan Section of the American Society of Mechanical Engineers, February 3, 1930, and published in the April issue of COMBUSTION. In the accompanying article, Dr. Hall summarizes certain facts established as a result of the work at the Kips Bay Station of the New York Steam Corporation, as described in Mr. Markson's paper, and presents an enumeration and discussion of additional considerations of importance in connection with boiler water conditioning.**

THE results of work by Markson, as described in subject paper, and those described in an earlier paper by Mumford (Vol. 51, No, 22 A. S. M. E. Transactions) establish several facts of importance regarding boiler waters:

(1) Even under the conditions of a large per cent of untreated make-up water and extremely high ratings such as characterize the operation at Kips Bay Station, steady maintenance of the requisite available phosphate in the boiler water in conjunction with suitable boiler water alkalinity, eliminates deposition of scale on the boiler surfaces.

(2) Exact limitation of the boiler water alkalinity is essential from the standpoint of preventing carry-over in the steam.

(3) Elimination of corrosion in economizers, regardless of deaeration, requires a pH value in the contacting water greater than neutrality. Since accumulation of this alkalinity in the concentrated boiler water is not permissible, alkali-reducing chemical must be introduced to obviate accumulation of alkali in the boiler water.

I would like to add four other conditions for the boiler water:

(4) It is as important that a minimum of alkalinity, corresponding to a pH value of 10—11, be maintained in the boiler water, as that the maximum be held within carefully defined limits.

(5) The boiler water must be kept as free as possible of saponifiable matter and organic contamination.

(6) It is important that the collective total of dissolved and suspended solids in the boiler water be held as low as possible. Therefore, every effort must be made to obtain the minimum concentration of dissolved solids in the feed water so that necessary limitation thereof in the boiler water shall not be purchased at the expense of excessive blowdown.

(7) Carbon dioxide is unessential and undesired in the steam. As all bicarbonates and carbonates entering the boiler water are largely decomposed with formation of caustic and carbon dioxide, their maximum elimination in the feed water is essential to insure a minimum of carbon dioxide in the steam.

If the boiler water is to meet these specifications, preparation therefor must be carefully made in choice of methods of processing the raw water.

Too frequently, the sole consideration in choosing the method for processing of the raw water is to obtain the utmost possible removal of scale-forming components therein. This is inept. Choice should be made to care properly for those other essential factors such as prevention of corrosion in pre-boiler lines and equipment, certainty and ease of boiler water alkalinity control, limitation of boiler water concentrations, and of the content of non-condensable gases in the steam.

From many sources, evidence is at hand that establishes the correctness of this position. In this discussion we will confine ourselves to the work of Mumford and Markson, which, in further establishing the soundness of our laboratory theory by its successful application to the tremendously severe conditions existent at Kips Bay, is sufficient proof that slight differences in hardness in the feed water are of minor significance. Thus the Croton water used as feed water (Table 1, No. 1) contains 9.6 p. p. m. of calcium and 3.5 p. p. m. of magnesium, or a total hardness of 38.5 p. p. m. expressed as calcium carbonate. Yet their problems have not been boiler-scale, but corrosion and scale in economizers, limitation of alkalinity in the boiler water, limitation of carry-over in the steam.

We may conclude, therefore, that with considerable latitude in the degree to which the calcium hardness of a raw water is reduced by primary processing, careful conditioning of the boiler water, as by Mumford and Markson, removes any cause for worry regarding deposition of scale on the boiler surfaces. Also, the well-entrenched, but in most cases erroneous bogey of corrosion due specifically to magnesium does not intrude, as prevention of corrosion is defined in terms of deaeration and pH value of the water. In fact, magnesium serves a very useful purpose by its alkali-reducing properties.

Having available the greater latitude in process-

ing the raw water, established by this conclusion, we can proceed to another conclusion: Wherever the heat-balance is such that installation of evaporators is economic, they should be installed. Also, the advantage of as high per cent of condensate return as possible is apparent. But on the other hand, these are not indispensable adjuncts to that cleanliness of surfaces essential for uninterrupted continuity of operation, and the engineer designing a plant need not necessarily sacrifice other desirable features or go to uneconomic costs, in order to include them, but may exercise his best judgment for greatest utility and economy.

Another factor relating to primary processing of the water should be emphasized. Bicarbonate is an undesirable constituent whether considered from the standpoint of its interference with maintenance of proper pH value in the feed water, that of its being a potential source of undesirable concentration of alkalinity in the boiler water, or whether it is troublesome because, by furnishing carbon dioxide to the steam, it heightens any corrosive tendency thereof. Were primary processing of the water possible at Kips Bay, removal of bicarbonate would aid in the problems relating to the economizers and to the boiler water alkalinities.

It seems to us that the preferred initial operation in any economic processing of a raw water containing any appreciable quantity of bicarbonate must comprise removal thereof as sludge by precipitation with lime. By its removal in this manner, there is left in the water a smaller content of dissolved solids than can be obtained through its removal by any commercial process other than evaporation. Its removal assures that the carbon dioxide therein will not finally be included in the steam as a contaminating gas. Its removal as the first step in processing the raw water simplifies both the protection of pre-boiler lines and equipment from corrosion, and the limitation of boiler water alkalinities to desired concentrations. Such removal possesses the same advantages for evaporator as for boiler feed water.

How general this principle is in its application may be seen from the following statement by Clarke, in Professional Paper 135 of the U. S. Geological Survey:

"As water carrying carbonic acid in solution is the primary agent of rock decomposition, it is an almost necessary inference that carbonates should be the principal salts in nearly all fresh waters. The following figures which, give the average composition of the river and lake waters of North America, excluding those of closed basins, may serve to emphasize this conclusion." (Table 1, No. 2).

It should be understood that the analysis, No. 2 of Table 1, is not an average of all North American fresh waters, but represents the average relative values of the different components in all such waters. By removal of the bicarbonate by precipitation with lime, a reduction in total solids of 35 per cent or more is effected. In consideration of the wide dissemination of this character of water, saving in blowdown alone by thus decreasing the dissolved solids in the feed water would represent no mean sum.

Following the initial step of bicarbonate removal, there is latitude in choice of further steps.

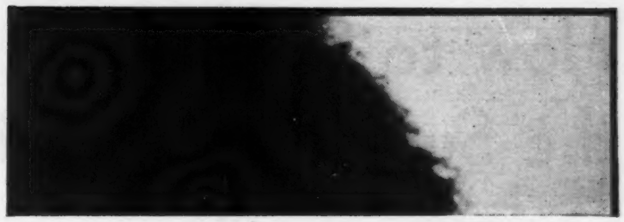
The facts on certain prevention of scale formation, presented by Markson, should be of special interest to engineers responsible for condensing plants using salt water for cooling water. No. 3 in Table 1 is an analysis of East River Water. No. 4 is City of Detroit Water. On the basis of calcium, condenser leakage of 1 per cent of East River Water is equivalent to 38 per cent of Detroit Water; and on the basis of chloride, to 2071 per cent of Detroit Water.

We suggest that a paper dealing with the problems of this latter type of plant and the methods of solving them would be eminently worth while.

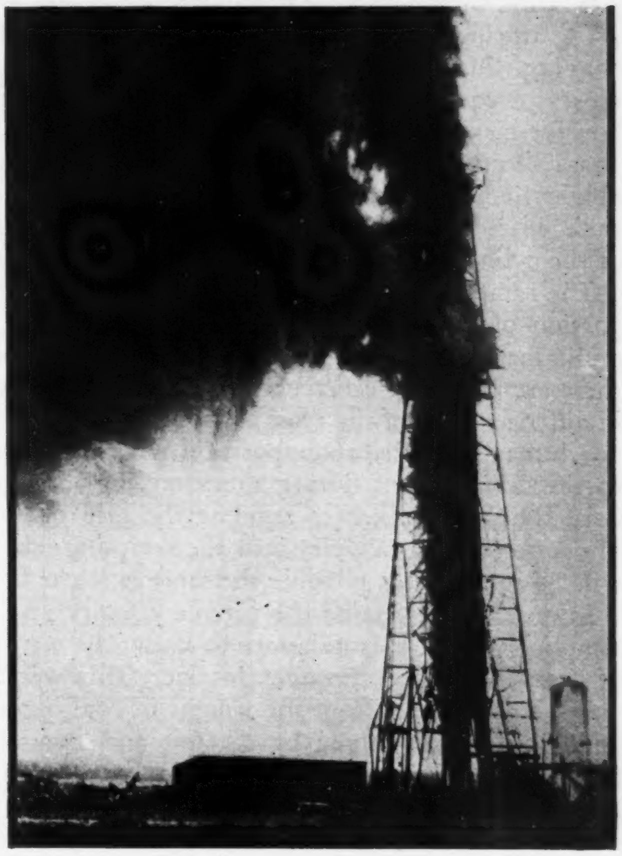
Table I

	1 Croton (a) Water p. p. m.	2 Relative Average (b) Composition of North American Waters p. p. m.	3 East (c) River p. p. m.	4 City of Detroit (d) Tap Water p. p. m.
Bicarbonate (HCO_3)	36.6	67.89	122	96.5
Sulphate (SO_4)	8.2	15.31	485	16.4
Chloride (Cl)	5.0	7.44	14500	7.0
Nitrate (NO_3)	0.6	1.15	.....	....
Silica (SiO_2)	9.0	8.60	13	2.8
Iron and Aluminum Oxides $(Fe, Al)_2O_3$	....	0.64	204	0.6
Calcium (Ca)	9.6	19.36	1002	26.2
Magnesium (Mg)	3.5	4.87	140	7.4
Sodium (Na)	3.2	7.46	8350	4.4
Potassium (K)	0.4	1.77	.....	....
Total dissolved solids (e)	....	100.00	.....	....

(a) Furnished by Bureau of Water Supply, Frank E. Hale, Director of Laboratories.
(b) U. S. Geological Survey, Professional Paper 135, p. 5.
(c) Analysis by Dr. A. H. Moody, Hell Gate Station.
(d) Water Dept., City of Detroit, Annual Report (1925–1926).
(e) Bicarbonate included as its equivalent carbonate, 33.40 p.p.m.



The World's Largest Gas Well Under Control



New well in South Oklahoma City field had free flow of 200,000,000 cubic feet of natural gas a day.

MARY SUDIK No. 1 has now been conquered. After a week's struggle early in April a crew of fifty men succeeded in capping this new well in the South Oklahoma City field, brought in March 26, from a depth of 6000 feet by Indian Territory Illuminating Oil Company a subsidiary of City Service and pioneer in the deep drilling development in the Oklahoma oil fields. The world's record for maximum gas output is claimed for this well, which until shut in, was flowing at the estimated rate of 200,000,000 cubic feet of natural gas a day under a pressure of 2000 lb. per square inch.

It is difficult to comprehend the enormous capacity of this new well. Based on thermal value, the daily output of gas is equivalent to 10,000 tons of midwestern bituminous coal. Only twelve states produce coal at a rate which exceeds the equivalent heat value of the gas from this single well.

The Consolidated Gas Company and associated companies which serve New York City and environs, meet an average daily demand of approximately 144,000,000 cubic feet of manufactured gas of around 525 B.t.u. standard. As the natural gas from the Oklahoma field has more than twice this heat value, the open flow of the Mary Sudik No. 1 well was roughly equivalent to three times the average output of the entire system of the Consolidated Gas Company of New York.

The job of shutting in a high pressure gasser is difficult and dangerous. With a flow pressure of nearly a ton per square inch, the huge steel cap, weighing over two tons, was tossed about like a straw in the wind endangering the lives of workmen who, according to news despatches, were working up to their waists in oil with the surrounding prairie flooded at the end of the struggle. In addition, the hazard of fire was ever present as any metal to metal contact might strike a spark and ignite the gas laden air and oil soaked ground.

The work of shutting in the Mary Sudik No. 1 was completed in less than a week. There are records of "wild" wells flowing for months before they could be capped and conquered.

Since this well came in, the mere initial show of oil steadily increased until at the time of shutting in, the flow spouting 400 feet in the air and visible at a distance of over eight miles, was estimated to exceed 60,000 barrels of oil a day. In addition to the record gas crown, this well holds promise of being one of the largest light oil gushers. The value of this oil is exceptional, not only because of existing pipe lines and the relative proximity of the refineries and markets, but it is lighter than most commercial gasolines. It is estimated that more than three quarters of this oil may be converted into gasoline.

A consideration of this new well emphasizes the tremendous commercial importance of the

(Continued on page 59)

How to Determine the Suspended Solids in Flue Gases

By B. J. CROSS

Combustion Engineering Corporation, New York

A DEVICE for drawing a sample of flue gas and separating the dust from it is shown in the accompanying illustration. It consists of a small cyclone separator equipped with a dust filter and an orifice box for measuring the flow of gas. The weight of dust collected is determined by weighing the removable cylinder and the steel wool of the filter with their dust content and subtracting the tare weight of the cylinder plus steel wool.

The sampling nozzle is best located in a vertical portion of the flue. The flue may be traversed in preliminary sampling to determine whether or not there are any great differences in dust concentration in different parts of the cross section. The sampling nozzle may be located at one position or may be moved to several positions during the sampling interval. Care should be taken to regulate the rate of flow of gas so that the velocity into the sampling nozzle will be as nearly as possible the same as in the flue.

In order to determine the correct velocity at the sampling nozzle, it is necessary to know the weight of gases discharged through the flue. This weight may be determined from the weight of coal burned under the boilers served by the flue and from the CO_2 content of the gases at the point of sampling, according to the method given in article No. 7 of this series. This weight should include both the dry gas and the water vapor and may be expressed in pounds of gas per minute. The fraction

$$\frac{\text{area of sampling nozzle}}{\text{area of flue at sampling point}}$$

gives the proportion of the total gases in the flue that must be withdrawn through the sampler to give the same velocity in the sampling nozzle as in the flue. Thus, if the duct has a cross section area of 25 sq. ft. or 3600 sq. in. and the area of the sampling nozzle is 7.07 sq. in. then $\frac{7.07}{3600}$ or .001963 represents the fraction of the total gases that must be passed through the sampler. If the flow of gas through the flue is 1500 lb. per minute then 1500 x .001963 or 2.94 lb. of gas per minute must be passed through the sampler.

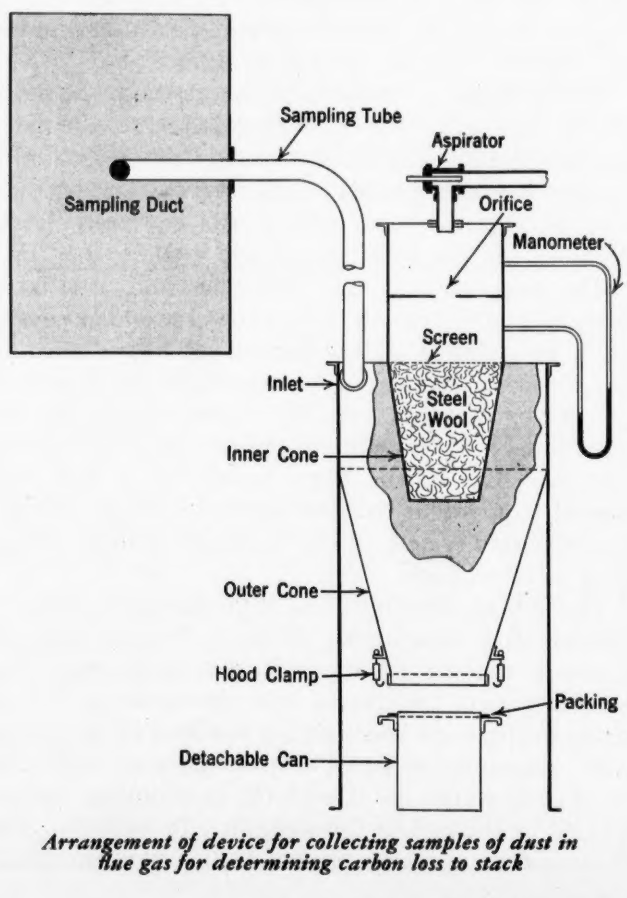
The sample of gases withdrawn may be measured by the drop in pressure across the orifice. The curves on the opposite page give a calibration of a 2 inch circular orifice for flue gas with a CO_2 content of 12 per cent by volume and at various temperatures. These curves have been constructed from the basic formula:

$$\text{Velocity (feet per second)} = C\sqrt{2\,gh}$$

Where g is 32.2 the acceleration due to gravity, h is the head, expressed in feet of gas and C an orifice constant which for this case has been taken as .65.

If the temperature of gas at the measuring orifice is 250 deg. fahr. then to draw the sample at a rate of 2.94 lb. per minute a pressure drop of .63 in. of water must be maintained across the orifice.

A sampling period of 2 to 3 hours is usually sufficient to obtain a sample for weighing and analysis. If the sampling period is prolonged the filter becomes saturated with dust and some of the finer dust will escape. If the sampler is used in an exposed place it should be insulated to prevent condensation of moisture. It is usually desirable to have a short connection between the sampling nozzle and the cyclone collector. However, when the gases to be sampled are at high temperature, the sampling pipe should be long enough so that the temperature of the gases may be reduced by the time they reach the sampler.



Arrangement of device for collecting samples of dust in flue gas for determining carbon loss to stack

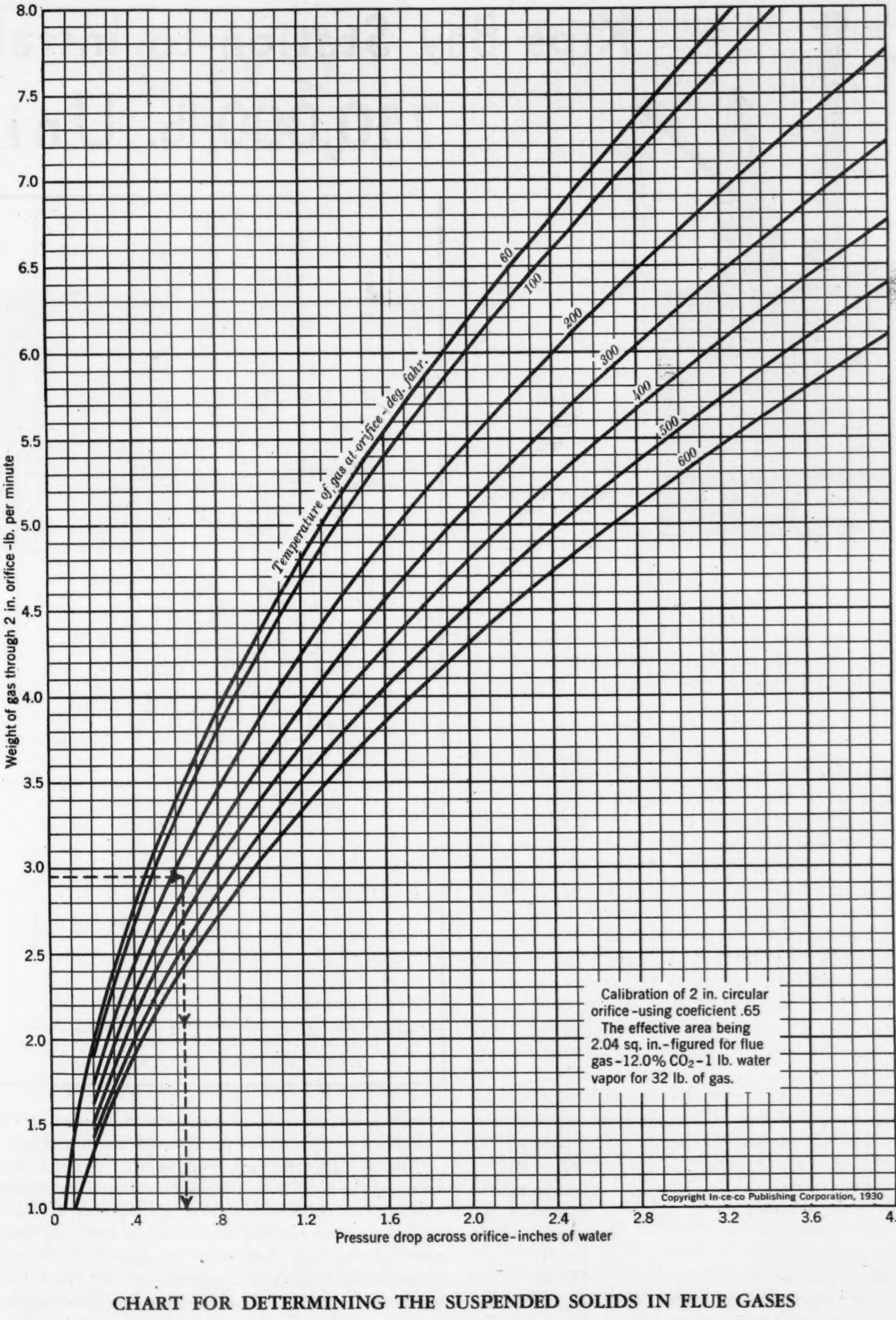
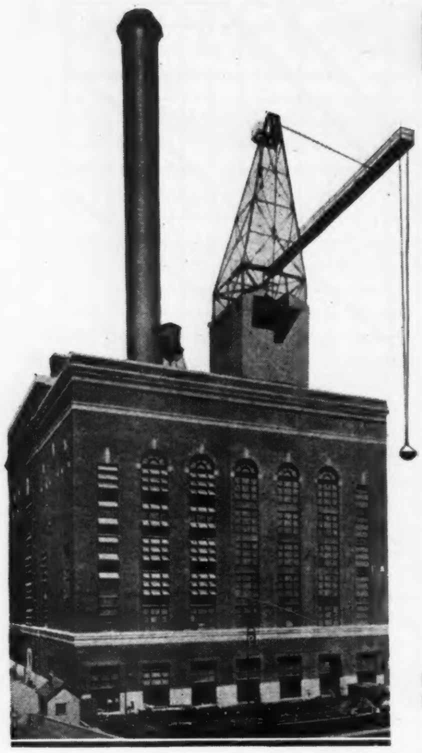


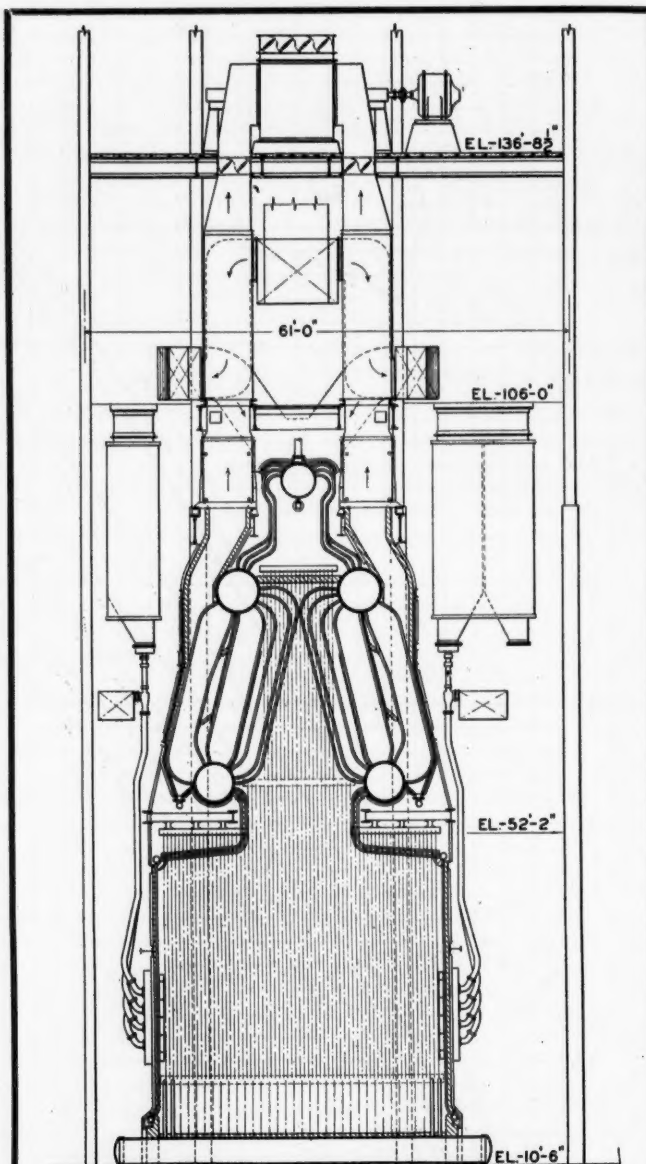
CHART FOR DETERMINING THE SUSPENDED SOLIDS IN FLUE GASES

No. 10 of a series of charts for the graphical solution of steam plant problems

Kips Bay Station to Install 750,000 lb. Unit



KIPS BAY STATION
N. Y. Steam Corporation



Sectional elevation of new 750,000 lb. unit

THE Kips Bay Station of the New York Steam Corporation is one of the most remarkable examples of concentrated steam production to be found anywhere in the world.

In 1926 this station was designed with six bays, each to accommodate a steam generating unit capable of developing 325,000 lb. of steam per hour. Three units of this size were installed.

Although the steaming capacity of the first three units exceeded expectations, steam demands also grew faster than estimated. Accordingly a fourth unit, designed to produce 375,000 lb. of steam per hour, was installed.

Within the past year construction has started on five new office buildings in the Grand Central zone, ranging from fifty stories to eighty-five stories in height, and all to be served by Kips Bay Station.

To provide for this increased steam demand, a fifth unit is to be installed, having a guaranteed steam capacity of 750,000 lb. per hour—nearly 2½ times the capacity of each original unit although occupying the same size bay. The details of this unit are:

Boiler heating surface	34,260 sq. ft.
Water wall heating surface	8,120 sq. ft.
Economizer surface	19,656 sq. ft.
Air Preheater surface	61,440 sq. ft.
Furnace volume	32,000 cu. ft.
Design pressure	300 lb.
Operating pressure	285 lb.
Liberation per cu. ft. of furnace vol.	28,700 B.t.u.
Maximum continuous steam output	750,000 lb.
Feed water temperature	200 deg. fahr.

Plant records show actual steaming capacities of 375,000 lb. for each of the first three units, and, a capacity of 450,000 lb. per hour for the fourth unit.

Contract for the new 750,000 lb. unit has been awarded to Combustion Engineering Corporation, which organization designed, manufactured and installed the fuel burning and steam generating equipment of the first four units at Kips Bay in close cooperation with the engineers of the New York Steam Corporation. This installation is a conspicuous example of cooperative engineering meeting a greatly increased steam demand without resorting to new buildings or increased land investment.

NEWS

Pertinent Items of Men and Affairs

Ralph A. Sherman Joins Battelle Memorial Institute

RALPH A. SHERMAN

BATTELLE Memorial Institute, Columbus, Ohio, announces the addition to its staff of Ralph A. Sherman to direct the program of research on combustion.

For the past ten years Mr. Sherman has been Fuel Engineer at the Pittsburgh Experiment Station of the U. S. Bureau of Mines, where he conducted investigations and published numerous reports on combustion problems. For several years he has had charge of the field investigations of refractories in boiler furnaces, which the Bureau of Mines conducted in cooperation with the Special Research Committee of the American Society of Mechanical Engineers.

Mr. Sherman has published papers on combustion studies in various types of furnaces and on powdered coal, and developed a method for determining the combustibility of coke.

Standard Oil Subsidiary Organized

Standard Management and Operating Corporation, a subsidiary of the Standard Oil Company of California, has been organized to direct and supervise the operation and development of public utilities and industrial establishments. It will also engage in engineering and construction work, and investigations.

At this time Standard Management and Operating Corporation has under its management the Pacific Public Service Company and its subsidiaries, consisting of Coast Counties Gas & Electric Company, California Consumers Company, California Consolidated Water Company, Coast Natural Gas Company and other public utility properties.

The offices of the new company are at 225 Bush Street, San Francisco, Cal. The following officers and directors are announced: E. F. English, President, R. W. Hanna, Vice-President, E. A. Olsen, Vice-President, R. N. Dreiman, Secretary, J. H. Tuttle, Treasurer.

Bituminous Coal Prices at Low Level

J. D. A. Morrow, President of the Pittsburgh Coal Company, Pittsburgh, Pennsylvania, states that, "The production of bituminous coal during the first quarter of 1930 indicates a decline of about nine per cent from the 1929 figures for the same period.

"Prevailing bituminous coal prices" according to Mr. Morrow, "are at the lowest level on record in the past thirteen years. The present conditions in the industry are expected to continue for another thirty to sixty days with a gradual improvement indicated after the middle of the year."

The Bailey Meter Company, 1050 Ivanhoe Road, Cleveland, Ohio, announces that it has transferred its office in Chicago, Illinois, to 20 North Wacker Drive Building. R. V. Knapp continues as branch manager in this territory where he is assisted by a staff of mechanical engineers specializing in metering control and combustion problems.

Cities Service Natural Gas Line Ready June 1

A twenty-inch natural gas pipe line having a capacity of 100,000,000 cubic feet daily, and connecting the midcontinent natural gas system of the Cities Service Company with the Oklahoma City natural gas fields of the Indian Territory Illuminating Oil Company, a Cities Service subsidiary, is scheduled for completion June 1.

This new pipe line will make available to the entire Cities Service gas system the resources of the Oklahoma City field, which approximate 600,000,000 cubic feet a day, open flow, from wells already completed. Indian Territory Illuminating Oil Company is reported to control 9,600 acres and royalty interest on 3,000 acres of oil and gas lands in the Oklahoma City field, which represents approximately 70 per cent of the proved area of the field.

Gas pressures, as high as 2,000 pounds per square inch, exist in this field and it is believed that the installation of compressors in the new pipe line, will not be necessary as the well pressure may be sufficient to carry the gas.

The Cities Service Company through various subsidiaries is reported to have under consideration several additional lines to pipe natural gas to various distributing companies throughout its extensive system.

The Terry Steam Turbine Company, has announced the election of J. D. Stout as vice-president with headquarters at the company's home office, Hartford, Conn. Mr. Stout has been associated with the Terry Company since 1909 and for the past several years has been manager of the company's New York office.

N.E.L.A. Convention at San Francisco

The Fifty-Third Annual Convention of the National Electric Light Association will be held Monday, June 16th to Friday, June 20th, inclusive in the Exposition Auditorium, San Francisco, California.

The preliminary announcement includes a Business Program of the highest order devoted to matters of vital concern to the industry, the various subjects being presented by the foremost authorities.

Following the precedent of former N.E.L.A. conventions held on the Pacific Coast, there will be no Manufacturer's Exhibit at San Francisco. However, a number of instructive Section, Bureau, Committee and N.E.L.A. Headquarters Exhibits will be held in the Exhibition Auditorium.

The Transportation Committee has arranged a number of interesting round trips from various cities in the east to the convention and return giving a choice of routes and including points of historic and scenic interest enroute. A descriptive booklet of the trip will be forwarded upon request to Robert B. Grove, General Traffic Manager, N.E.L.A. c/o The United Electric Light & Power Co., Room 616, 4 Irving Place, New York City.

The Dampney Company of America, Hyde Park, Boston, Mass. announces the opening of a direct company branch office at 305 Thomas Building, Dallas, Texas. J. Dwight Bird will be in charge of the Southwestern Territory.

The Dampney Company also announces that Edward L. Clark, formerly associated with the Westinghouse Electric & Mfg. Co. and the H. R. Kent Engineering Co., will be in charge of the New England Territory, maintaining his offices in Boston.

Allied Engineers Organized

The Allied Engineers, Inc., has been formed to take over the assets, business and organizations of Stevens & Wood, Inc., Dixie Construction Company and the Empire Construction Company, according to a recent announcement made by B. C. Cobb, chairman of the Commonwealth and Southern Corporation. The Allied Engineers will continue in the present location of Stevens & Wood, at 60 John Street, New York until May 1, when it will move to offices at 120 Wall Street, New York.

E. A. Yates will be chairman of the board and B. F. Wood will be president. Other directors are B. C. Cobb, Thomas W. Martin, Jacob Hekma, T. A. Kenney, E. A. Yates, H. G. Kessler, F. P. Cummings, W. H. Sawyer, O. G. Thurlow, W. H. Bathold and B. F. Wood.

Combustioneer, Inc., manufacturer of automatic coal burners will move its factory and general offices to Goshen, Indiana, May 1st. District Warehouse and Service facilities have been established at 1801 West Madison Street, Chicago, Ill.

International Railway Fuel Meeting

The Twenty-Second Annual Convention of the International Railway Fuel Association will be held May 6 to 9 inclusive at the Hotel Sherman, Chicago.

This association with a membership of over 1700 railway officials, equipment manufacturers and representatives of fuel companies, is dedicated to the efficient preparation, distribution and use of fuel. The annual fuel purchases of Class I railroads are reported as amounting to $400,000,000.

In addition to the regular business sessions of the Association, the program includes a number of technical papers on various phases of fuel utilization.

The Texas Company announced the removal of its New York offices to 135 East 42nd Street, New York City, effective April 7, 1930.

Warren C. Drake, 5 Beekman Street, New York City has been appointed representative of the Boiler Engineering Company, Newark, N. J., for the sale of BECO Boiler Baffle Walls in the Metropolitan District.

Consolidated Gas Begins Hunt's Point Improvement

Consolidated Gas Company of New York has started work on extensions to its Hunt's Point Gas Plant which will cost approximately $4,500,000.

The new work will include thirty-seven coke gas ovens which will provide an additional capacity of 10,000,000 cu. ft. of gas per day. Seventy-four coke gas ovens now in service at Hunt's Point have a capacity of 20,000,000 cu. ft., use 1,750 tons of coal a day and produce 1,200 tons of coke, part of which is used in the plant and the balance sold for domestic use.

The new addition will increase the daily coal consumption to 2,625 and the coke yield to 1,800 tons.

The plant extension is scheduled for completion by next January.

R. S. Coulter, who has been combustion engineer at the Sparrow's Point plant of Bethlehem Steel Company for the past eleven years, has resigned his position to devote his entire time to the private practice of consulting combustion engineer with headquarters at Lebanon, Pa.

Grindle Fuel Equipment Company a subsidiary of Whiting Corporation, Harvey, Illinois, announces the appointment of R. J. Bender as Combustion Engineer in Charge of Development. Mr. Bender has been identified with the pulverized coal field for the past ten years, in America and abroad.

Whiting Corporation, Harvey, Ill. announces the appointment of E. F. Lindsay as sales manager of its Harrington division, in charge of stoker sales.

REVIEW OF NEW TECHNICAL BOOKS

Any of the books reviewed on this page may be secured from In-Ce-Co Publishing Corporation, 200 Madison Avenue, New York

Mechanical Engineering Laboratory Practice

By Charles F. Shoop *and* George L. Tuve

WHILE this book is intended primarily as a text for use in laboratory work in connection with courses in the theory and practice of heat power engineering, it will serve as a valuable reference book for all who are engaged in experimental work in this field, as well as for those who have occasion to conduct tests in connection with steam plant equipment.

Following some general instructions on laboratory practice and report writing, there is a chapter entitled, "Mechanical Measurements—Methods and Instruments," which relates to the measurements of pressure, temperature, volume, weight, velocity, areas and power. Succeeding chapters are devoted to typical laboratory studies, properties and tests of lubricants, and friction tests on lubricated and non-lubricated surfaces. Then there is a chapter on heat and heat transfer which is divided into several sections, one of which pertains to theory and one to heat losses from bare and covered pipes. The next two chapters relate respectively to the properties of gases and vapors, and the measurement of fluid flow.

The two chapters following are of particular interest to steam plant engineers since they treat very comprehensively of tests and test methods in connection with boilers, turbo-generators, pumps, compressors and other auxiliaries. In each case, the procedure for testing is outlined in detail and the necessary equipment indicated. This part of the book also describes methods of analyzing coal, liquid and gaseous fuels, flue gases or products of combustion, and boiler water. There is also a chapter on automatic regulation.

The chapters mentioned here indicate the scope and nature of the book and the amount of material it contains which is germane to the interests of steam plant engineers.

The book throughout is well illustrated and includes a number of suggested forms for the tabular arrangement of test data. Although the inclusion of an ample number of reference tables, diagrams, etc., make the book self-sufficient, comprehensive references are given to standard texts and recent technical papers in the various fields covered. There is also a fifty-page appendix which contains much useful information. The volume is bound in cloth covers, 6½ by 9⅜ overall, and contains 490 pages. The price is $3.00.

Steam Generation Steps Ahead

By G. B. Gould

THIS interesting and exceedingly readable book merits a thorough reading by all engineers and executives who have to do with the design of coal-burning steam plants, particularly those plants which may be regarded as comprising the middle-class group.

Its major emphasis is on the selection of the most suitable and economical coal, but, as the author points out, this problem is so closely inter-related with the factors of plant design and plant operation that it cannot be divorced from these considerations. Too often the problems of plant design and equipment selection are not sufficiently influenced by the fuel question and the result is that the completed plant is unnecessarily limited with respect to the available coals it can burn.

Then again, the variables in plant operation may cause one coal to appear better, in terms of heat absorption, than another which would seem preferable from the standpoints of relative analyses and costs. In such cases a heat balance, indicating the nature and extent of the losses, furnishes the answer to the problem and may reveal certain weaknesses in operation which would make the second coal the more economical.

Since coal, in the average, represents from two-thirds to three-quarters of the total cost of steam, the importance of correct analysis and co-ordination of the three factors,—coal selection, equipment selection and plant operation, is so apparent as to need no demonstration. The comprehensive discussion of these factors, separately and collectively, which is presented in this volume, should further the work of reducing the cost of fuel for steam generation, particularly with respect to the small and medium size steam plants where the opportunities for savings in this direction are so considerable.

The last chapter of the book considers economic and engineering trends in steam generation, especially as they affect the purchase and use of coal.

This book is attractively bound in stiff covers, 5 by 7¾ overall, and contains 102 pages. The price is $1.00.

NEW EQUIPMENT

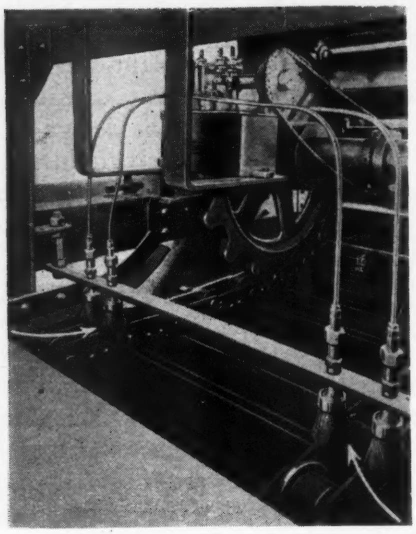
of interest to steam plant Engineers

Force Feed Lubricator

THE Hills-McCanna Company, 2349 Nelson Street, Chicago, has developed a unique application of force feed lubrication to mechanical conveyors of the link and roller type. The illustration shows an installation of a forced feed lubricator to a heavy duty apron conveyor—a difficult oiling problem.

The lubricator is shown mounted on the under or slack side of the conveyor. Oil is forced, by the Pump, to the brushes shown through 1/4 inch O. D. copper tubing. As each link in the chain passes beneath the brushes it is coated with a film of oil. The lubricator used on this installation is a four feed unit driven by a sprocket and chain from the main drive shaft of the conveyor.

Hills-McCanna Force Feed Lubricators are built in several sizes ranging from pint capacity single feed units for use on small equipment pumps and the like, to large units having as many as 60 feeds. These units may also be mounted in tandem fashion, operated by a central driving unit, thereby increasing



the number of feeds to any desired quantity. These larger units permit lubrication of several related machines at regular intervals with predetermined amounts of oil.

Stoker for Low-Set Boilers

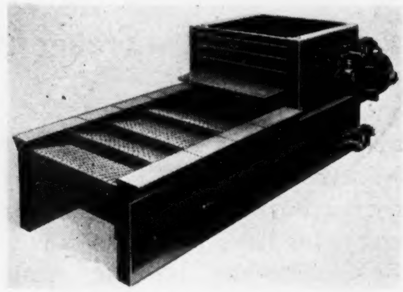
THE Whiting Stoker for small boilers from 25 hp. to 250 hp. has been placed on the market by the Harrington Division of Whiting Corporation, Harvey, Illinois. The Model "C" design which is illustrated on this page requires less setting height than most other stoker equipment. This characteristic enables this stoker to be installed under boilers where it would hardly be possible to install other stokers and secure sufficient combustion space. The correspondingly lower position of the hopper makes it easier to fill.

The Whiting stoker represents an entirely original design, exclusively developed for small boilers. It is not a mere adaptation of a larger stoker model.

The movement of the fuel bed is horizontal. This makes it possible to maintain an even fuel bed of uniform thickness without holes, mounds or tapering off, and permits the correct application of air at low static pressure.

The blower and operating mechanism are mounted in permanent alignment on the door thus eliminating costly air ducts.

The action of the grate mechanism results

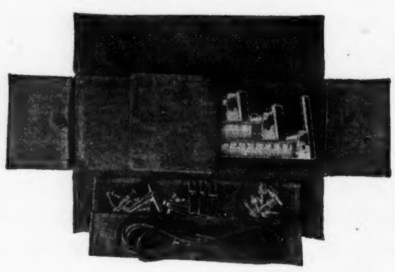


in a steady progression of the fuel bed from coal to ash. The ash and refuse is automatically and continuously discharged as formed from the rear of grates to the ash pit below.

Portable Draft Gages

A CONVENIENT portable draft gage outfit was recently introduced by The Defender Automatic Regulator Company, St. Louis, Mo. The illustration shows the standard combination which includes three inclined draft gages, an all-metal oil tube container with a seal screw top cap and accessories all enclosed in a durable, waterproof carrying pouch of imitation leather.

The gages fit together in a compact group when packed. The top gage has a 5 in. scale which can be furnished to read to either 1/2 in. or 1 in. of draft. The center gage has a 7 1/2 in. scale graduated to read either 3/4 in. or 1 1/2 in. The lower gage has a 10 in. scale and is graduated to 2 in.



The carrying pouch is designed to protect the gages and to provide pockets for fittings and accessories necessary to taking draft reading, such as micrometer adjustments, screw driver, gimlet, oil dropper, mounting screws and connecting plugs. Each gage is also provided with a nickel plated draft tube which is connected to the rubber tubing and then inserted into the furnace or breaching when taking draft readings.

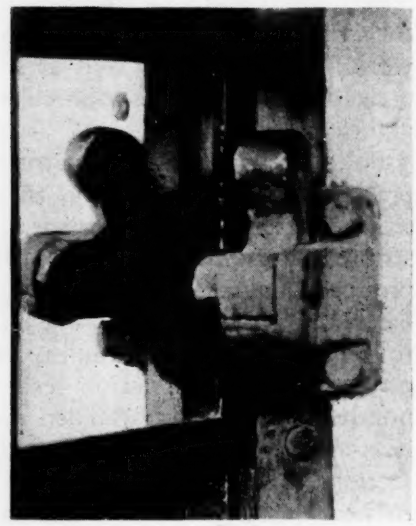
The over all size of the outfit when packed is 14 in. long, 4 1/4 in. wide and about 1 1/2 in. thick. Total weight—2 1/2 lb.

Furnace Door Safety Latch

THE DeWaters Automatic Safety Latch Corporation, 122 East 42nd Street, New York, has developed an automatic safety latch for furnace doors.

The protection of human life and property in boiler rooms presents a great need for a simple and practical means for holding the fire doors securely shut against any sudden release of pressure in the furnace in case of a tube rupture or blow-off pipe breakage, or against the force of a furnace gas explosion. The effect of a tube rupture or a blow-off pipe break is usually to blow fire or red-hot coals out of the furnace doors, enveloping everybody and everything within reach—there is a long list of casualties that have resulted from this ever-present menace. Furnace gas explosions frequently shoot a large volume of flame out of the furnace doors with equally disastrous results.

The DeWaters Automatic Safety Latch is of the over-locking type with counter-



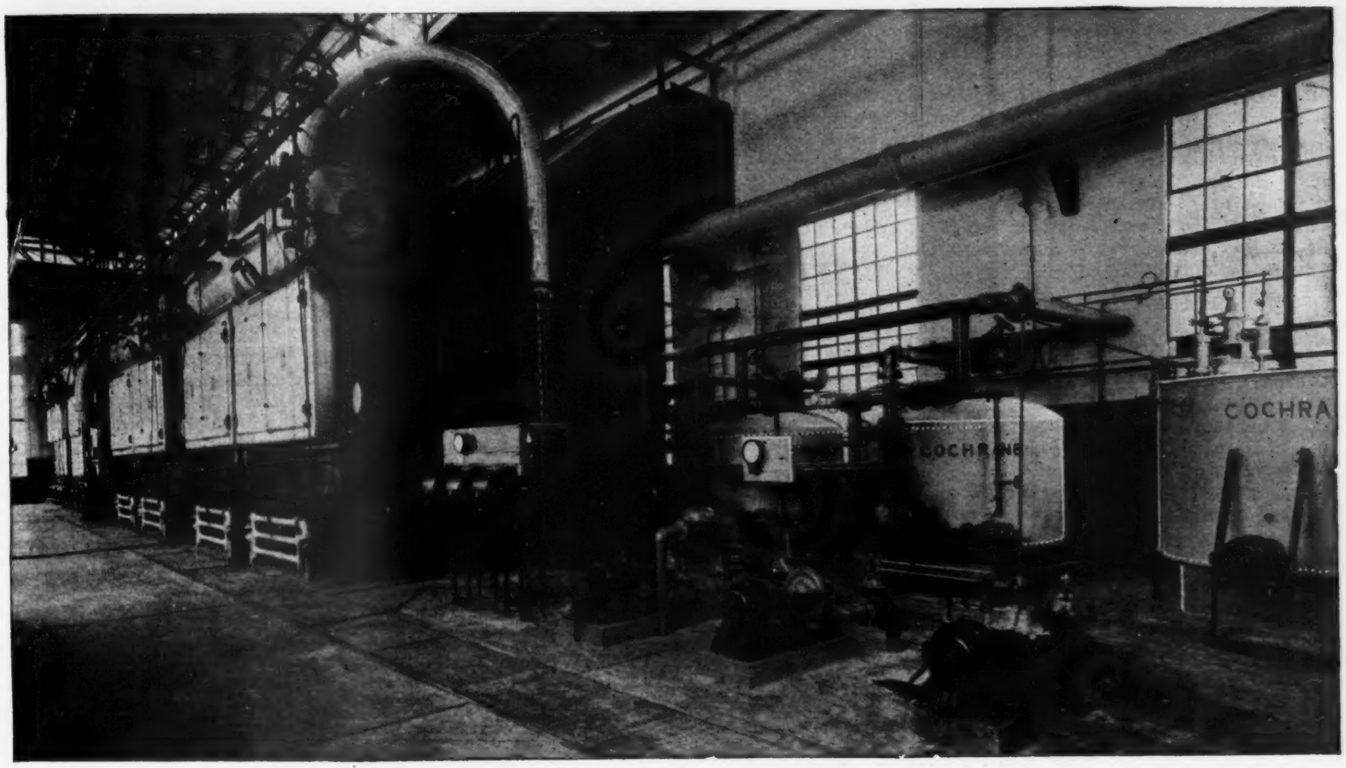
weighted handle and controlled movement, so designed as to be unfailing in its locking whenever the door is moved to the closed position. It is designed to positively catch and hold, no matter whether the door is closed gently or is forcibly slammed shut. The proper balancing of the latch prevents the door from rebounding open.

The device consists of a latch member, that is supported by a latch block, fastened to the furnace door, and catch lug, attached to the door frame. The unlocking movement of the latch is limited by the stop bracket underneath, so that the backward movement is just sufficient for the lip of the latch to clear the catch lug. In this position, the door can be opened freely, the knob serving as a convenient handle. When not held in this unlocked position, the latch drops into the locked position due to the weight of the knob, and it is then in readiness to engage with the catch lug and lock securely whenever the door is closed.

The illustration, taken by means of a mirror, shows two views of the latch in the locked position.

The DeWaters Automatic Safety Latch is said to be the only latch that has been approved as meeting all the requirements of the inspection authorities, including the Boiler Code Rules of the American Society of Mechanical Engineers as enforced by the members of the National Board of Boiler and Pressure Vessel Inspectors, and has been tested and listed as "Standard" by the Underwriters Laboratories. All parts of the latch are made of heat-treated cast steel.

AVOID EMBRITTLEMENT CORROSION . . . . SCALE



A Cochrane Softener installation, which is saving directly $5,668.45 per year, besides increasing boiler reliability and capacity.

THE COCHRANE HOT PROCESS for conditioning boiler feed water gives effective control of the composition of the boiler water.

1—Scale-forming solids are precipitated externally in a sedimentation tank and filter, rather than in the boiler itself.

2—Oxygen is eliminated from the water before it enters the boiler, which gives complete protection against corrosion or pitting.

3—The ratio of alkalinity to sulphate in the boiler water can be so controlled as to avoid any tendency to embrittlement of the boiler steel, irrespective of the original nature of the water.

The COCHRANE SOFTENER retains its capacity and efficiency indefinitely and is correctly operated by men of ordinary intelligence following our printed instructions. The experience of leading steam users in all parts of the United States has demonstrated that it is

BEST FOR BOILERS

Send analysis of your water supply and state operating conditions so that we may send history of results obtained in plants having similar conditions.

Ask for Bulletins IC-670 and 678

COCHRANE CORPORATION

3160 North 17th Street, Philadelphia, Pa.

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NEW CATALOGS AND BULLETINS

Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Ash Conveyor

The Nuveyor, a pneumatic conveyor is described in a new Bulletin No. 201. This conveyor is adapted to conveying stoker ash, powdered fuel ash, soot, coal and all dry, granular, abrasive materials. In a single operation the material is drawn from its places of accumulation direct to storage. An airtight storage tank is not required. Steam flow is turned on and off by push button control at each ash intake. A combined air washer and silencer is included in the system. A typical application arrangement of the conveyor is illustrated to show the salient features of the Nuveyor system. 4 pages, 8½ x 11—United Conveyor Corporation, Old Colony Building, Chicago.

Back Pressure Valve

The Cochrane Cushion Type Back Pressure Valve is illustrated and described in Bulletin 1682. This valve is of the multiple disc type and is spring loaded. The use of several small discs instead of one large disc eliminates failure by sticking and avoids the shock, noise and wear incidental to the hammering of a large disc upon its seat. Distortion due to temperature changes is also very much less in the smaller discs. The back pressure can be readily adjusted between the maximum pressure for which the valve is designed and free exhaust. 6 pages, 8½ x 11—Cochrane Corporation, 17th Street and Allegheny Ave., Philadelphia, Pa.

Boiler Water Conditioning

In a new booklet, "Scientific Research Solves the Boiler Water Conditioning Problem," Dr. R. E. Hall, formerly with the U. S. Bureau of Mines, explains the discovery and development of a new, molecularly dehydrated, boiler water conditioning chemical, Hagan Phosphate, for the prevention of scale, corrosion and foaming in steam boilers. This practically neutral chemical reduces alkalinity and provides phosphate to prevent scale formation. Unlike ordinary phosphates, the chemical prevents calcium deposits clogging the feed line system, as with this treatment, the calcium salt is readily soluble in the boiler itself. Practically neutral, it maintains proper alkalinity in the feed water for prevention of feed line and economizer corrosion. Other advantages of low, controlled alkalinity are: minimum foaming and carry-over, ease in maintaining recommended sulphate-alkalinity ratios for prevention of embrittlement and wet steam. 30 pages and cover, 8½ x 11—Hagan Corporation, Pittsburgh, Pa.

CO_2 Meters

Leeds and Northrup CO_2 Meters (Electrical) are illustrated and described in a new bulletin No. 781. A number of charts are presented to show the relation of CO_2 and excess air, the effect of hydrogen in fuel, loss due to excess air and other information pertaining to combustion. Numerous diagrams show the principles of design and typical installation arrangements. Sample charts from CO_2 recorders, and temperature recorders are included in the back of the bulletin. 24 pages and cover, 8½ x 11—Leeds & Northrup Company, 4901 Stenton Avenue, Philadelphia, Pa.

Draft Gage

The Ellison Pointer Draft Gage, presented in Bulletin No. 10-B, is of the gasometer bell, beam and pointer type and is made in single- and multi-pointer units, for either panel or wall mounting. Both vertical and tilted front types are available, the latter being designed to permit correct vision of the scale when the gage is mounted at a considerable height above the firing floor.

The "straight-line" pointer movement was developed to insure greater accuracy and better visibility. 8 pages, 7¾ x 10¾—Ellison Draft Gage Company, 214 West Kinzie Street, Chicago, Ill.

Feed Water Regulator

A new bulletin describes the Copes Type RG combined Feed Flow-Water Pressure Regulator, which maintains the exact predetermined water pressure differential across the control valve. It controls, accurately and positively, the amount of valve opening. Thus, by close regulation of these two factors, the Type RG Regulator gives the exact water input required and maintains a stabilized boiler water level, regardless of changes in load or excess water pressure at the feed pump. 4 pages, 8½ x 11—Northern Equipment Company, Erie, Pa.

Fire Box Boiler

Coatesville Fire Box Heating Boilers are briefly covered by new Bulletin No. 88. This boiler is built in four designs — Series "A" for Anthracite Coal; Series "B" updraft bituminous coal; Series "C" oil or gas, and Series "D" downdraft bituminous coal. Twenty-three sizes are available in each design. The salient features of this series of boilers are: (1) No crown stays, (2) Gastight packed door joints, (3) Integral steam separator standard equipment for all sizes (4) Smoke box insulated. 4 pages, 8½ x 11—Coatesville Boiler Works, Coatesville, Pa.

Pumps

"Pump-Fax" is the title of a new and comprehensive hand book on Pumping, compiled by F. G. Switzer, Professor of Hydraulic Engineering, Cornell University. A wealth of information is presented on various types of pumps, how to figure head, discharge and power required. Chapters on installation and operation are included. This hand book will be a valuable addition to the library of any engineer whose work includes problems in pumping. 64 pages and cover, 8½ x 11—Goulds Pumps, Inc., Seneca Falls, N. Y.

Steam Purifier

Bulletin 1054 presents the Tracyfier, a steam purifier that removes dirt and moisture and assures continuous delivery of clean, dry steam. The Tracyfier takes the place of, and occupies the same space as the old boiler dry pipe. It consists essentially of a rectangular steel box, located in the steam space of the boiler drum, immediately below and connected with the steam nozzle. All steam before leaving the boiler must pass slowly and circuitously through the several rows of staggered baffles which divide the steam into thin sheets. 20 pages, 8½ x 11—Andrews-Bradshaw Company, division of Blaw-Knox Company, Pittsburgh, Pa.

Steam Trap

The Armstrong Steam Trap described in new catalog F, is of the inverted, submerged bucket type and is offered as a simple reliable and automatic trap. In operation, steam floats the inverted submerged bucket and closes the outlet valve. Water entering the trap fills the bucket which sinks, and through compound leverage opens the valve and the trap discharges. The action, both opening and closing is quick and positive. Information on the installation and maintenance of steam traps is included. 36 pages, 6 x 9—Armstrong Machine Works, Three Rivers, Mich.

Underfeed Stoker

The Leffel Automatic Underfeed Stoker for Scotch Marine and other internally fired boilers is presented in a new illustrated bulletin No. 217. The stoker is made in sizes from 15 hp. to 200 hp. It is usually furnished with electric motor drive although steam turbine drive can be provided if desired. The rate of coal feed and air supply are both automatically controlled by the steam pressure of the boiler. The gearing is fully enclosed and dust proof, operating in a bath of oil. 4 pages, 8½ x 11—The James Leffel & Company, Springfield, Ohio.

Water Softener

The Scaife Siphon Continuous Water Softener is described in Bulletin 202-A. This softener operates automatically to introduce reagents in direct ratio to the volume of water and independent of any moving mechanical device. The siphon reagent feeding device operates directly from the inflowing water automatically regulating the volume of reagents to varying volumes of water — the principle being that of a main raw water siphon actuating an auxiliary reagent solution siphon so that the two flow in unison. 8 pages, 8½ x 11—Wm. B. Scaife and Sons Company, Oakmont, Pa.

Welded Piping

A new book, "Oxwelded Construction for Modern Piping Service," presents facts pertinent to, and advantages of, the oxy-acetylene process for the fabrication of steel and wrought-iron piping systems for all purposes. Eight chapters comprise the book. The first three of these are general in character and the remaining five apply to particular fields of piping construction. 80 pages and cover, 6 x 9—The Linde Air Products Co., 30 East 42nd Street, New York.

NOTICE

Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature to

COMBUSTION
200 Madison Ave., New York

The Thermal Properties of Steam

(*Continued from page 39*)

The specific volume of wet steam is equal to the sum of the volumes of the fractions of liquid and vapor contained therein; that is, $x\ v_g + y\ v_f$, where v_g and v_f are the specific volumes of dry saturated steam and of saturated water at the pressure and temperature of the wet steam. Due to the fact that v_f is generally very small relative to v_g, the volume of the moisture may be neglected when the moisture fraction is small.

The entropy of wet steam is given by $s_f + x\ s_{fg}$ or by $s_g - ys_{fg}$, where s_f and s_g are the entropies of the liquid and the vapor respectively and s_{fg} is the entropy of evaporation.

References

The article, "Steam" from the 1797 edition of the Encyclopedia Britannica was reprinted in the second volume of John Robison's "A System of Mechanical Philosophy" published in 1822. Dixon's "Treatise on Heat" prepared in 1849 for the use of students in the School of Engineering of the University of Dublin, describes the experiments made up to that time on the pressure-temperature relation and the specific volume of steam. The experiments of Regnault were published in three volumes dated 1847, 1862 and 1870, repectively, under the title, "Relation des experiences par ordre du ministre des travaux publics pour determiner les principales lois et les donnees numeriques qui entrent dans le calcul des machines a vapeur." The first volume contains the experimental results on the pressure-temperature relation for saturated steam, on the latent heat of steam and on the specific heat of water. The third volume contains the experimental results on the specific heat of superheated steam.

Discussions on the experimental data utilized in the preparation of steam tables by Marks and Davis and by Goodenough will be found in connection with their published tables. Callendar's book on the Properties of Steam, published in 1920, contains an interesting discussion of the subject. The progress of the A. S. M. E. steam research has been given in Mechanical Engineering each year since 1923. The issue of February, 1930, contains a report on the International Steam Table Conference held in July, 1929. A compilation of the more reliable recent experimental data on which the Keenan Steam Tables are based, was given by Davis and Keenan in the December, 1929, issue of Mechanical Engineering. The several articles in Glazebrook's Dictionary of Physics on Calorimetry and the article on Latent Heat contain descriptions of experimental apparatus and procedure used in measuring the thermal properties of steam and their fluids. Parts of the article on Thermodynamics will be found of interest regarding the continuity of the gaseous and liquid states.

The World's Largest Gas Well Under Control

(*Continued from page 47*)

vast natural gas fields which are exerting a rapidly increasing influence on the industrial areas which they serve. Natural gas from Louisiana is available in Birmingham and Atlanta, while Denver, Kansas City and St. Louis are served from the fields of the Texas panhandle. Two twenty-four inch pipe lines, nine hundred miles long, are being built to supply natural gas to Chicago, and, it has been said that natural gas will reach New York City within the next five years.

In the Oklahoma City field where Mary Sudik No. 1 is located, the Indian Territory Illuminating Oil Company alone owns 9000 acres of proven area with ninety-four producing wells having a total initial production of approximately 800,000 barrels of oil and 600,000,000 cubic feet of natural gas a day. However, the present oil production is limited to 50,000 barrels a day as this is the maximum capacity of available transportation facilities.

Natural gas is assuming increasing importance as an industrial fuel, and industry stands ready to absorb the capacity of many Mary Sudik No. 1's as fast as pipe lines and distribution facilities are made available.

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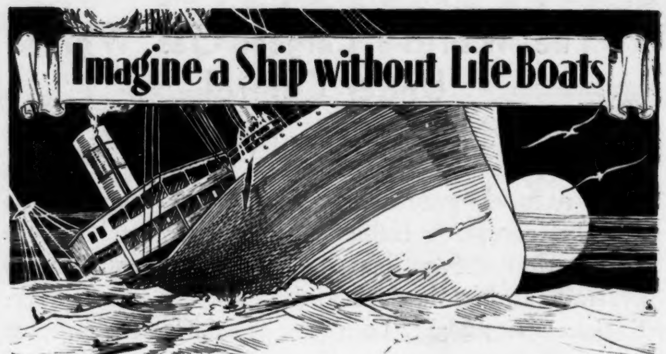

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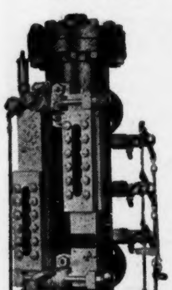

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